Public Safety Considerations for Automated Driving System (ADS) Deployment

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Introduction

AS AUTOMATED DRIVING SYSTEMS (ADS) and advanced driver-assistance systems (ADAS) are integrated into the U.S. vehicle fleet, the role of the human driver is changing. Traditionally, the human driver is in full control of operating a vehicle through each driving task; however, ADS and ADAS are steadily advancing and moving the human driver's role to that of a fallback-ready user. As technology advances and the role of the human shifts away from that of a traditional driver, so will the interactions that first responders, such as law enforcement, fire and rescue, and emergency medical services (EMS), will have with civilian vehicles.

Industry experts expect the deployment of ADS-equipped vehicles to increase safety by removing human error from the driving task (IIHS and HLDI 2022). Other potential benefits of autonomous vehicles include more efficient use of land, resources, and highway systems. Third party–owned vehicles, sometimes referred to as fleet managed vehicles, that the public can use for travel when needed as opposed to owning vehicles would increase land use efficiency and lessen the need for parking structures, especially in urban centers (Bajpai 2016). Ridesharing would have a large impact on travel efficiency in urban areas and a positive environmental impact due to less reliance on individually owned and operated vehicles.

ADS technology has the potential to virtually eliminate the need for police resources for enforcing traffic safety laws, as these vehicles will be programmed only to follow the rules of the road (Winston 2020). This concept is backed by Woods (2019), who suggested that traffic stops, at the very least, could be nearly eliminated because ADS vehicles will be programmed to obey the law. In addition, sensory technology could reduce collisions with other vehicles or people; licensure requirements may be eliminated, resulting in less need for enforcement of drivers' license laws; driving under the influence (DUI) law reforms could abolish the need for DUI stops; and ADS technologies may reduce the staff power required for investigations of hit-and-run offenses and traffic violation investigations altogether (Woods 2019).

However, while ADS advancements may reduce many common law enforcement interactions, they will not eliminate the need or opportunity for improved interactions between first responders and ADS-equipped vehicles. Disasters, incident responses, and a multitude of other circumstances will still require first responders, and especially law enforcement, to cross paths with these vehicles. One future posited by Gregg (2019) predicted that as the technological advancements of ADS become more commonplace, the average law enforcement agent may require enhanced IT skills as part of their practical skillset.

The remainder of this white paper presents a summary of the scenarios or use cases in which law enforcement commonly interacts with stakeholders and vehicles and the key takeaways of stakeholder outreach efforts mapped against the literature findings to determine critical gaps between law enforcement and ADS developers.

Methods

THIS WHITE PAPER IS THE CULMINATION OF SEVERAL TASKS that included a literature review to develop a comprehensive list of potential interactions between law enforcement and drivers or vehicles and stakeholder outreach to identify knowledge gaps among law enforcement and the challenges facing law enforcement when interacting with ADS-equipped vehicles. Knowledge gaps, or areas where stakeholder and original equipment manufacturer (OEM) understanding were determined to be inconsistent, were identified through two key activities: (1) survey outreach and (2) subject matter expert (SME) focus groups and interviews.

Survey outreach

A Qualtrics survey was developed to determine law enforcement's experience with ADAS- and ADS-equipped vehicles, concerns regarding these vehicles, and preferred educational approaches. Respondents were recruited through the International Association of Chiefs of Police (IACP) membership newsletters and announcements and at conferences attended by both IACP and Virginia Tech Transportation Institute team members. A total of 378 individuals completed the survey (figure 1 on page 4). These individuals represented a range of department sizes (figure 2 on page 4) and types and locations (figure 3 on page 5). Of all respondents, 14 said they had received information, guidance, or training on ADAS-equipped vehicle-related features from their agency and five said they had received guidance on ADS-equipped vehicle features. Twenty-seven respondents were aware of ADS-equipped vehicle deployments within their jurisdictions.

Figure 1. Distribution of survey respondents across the United States

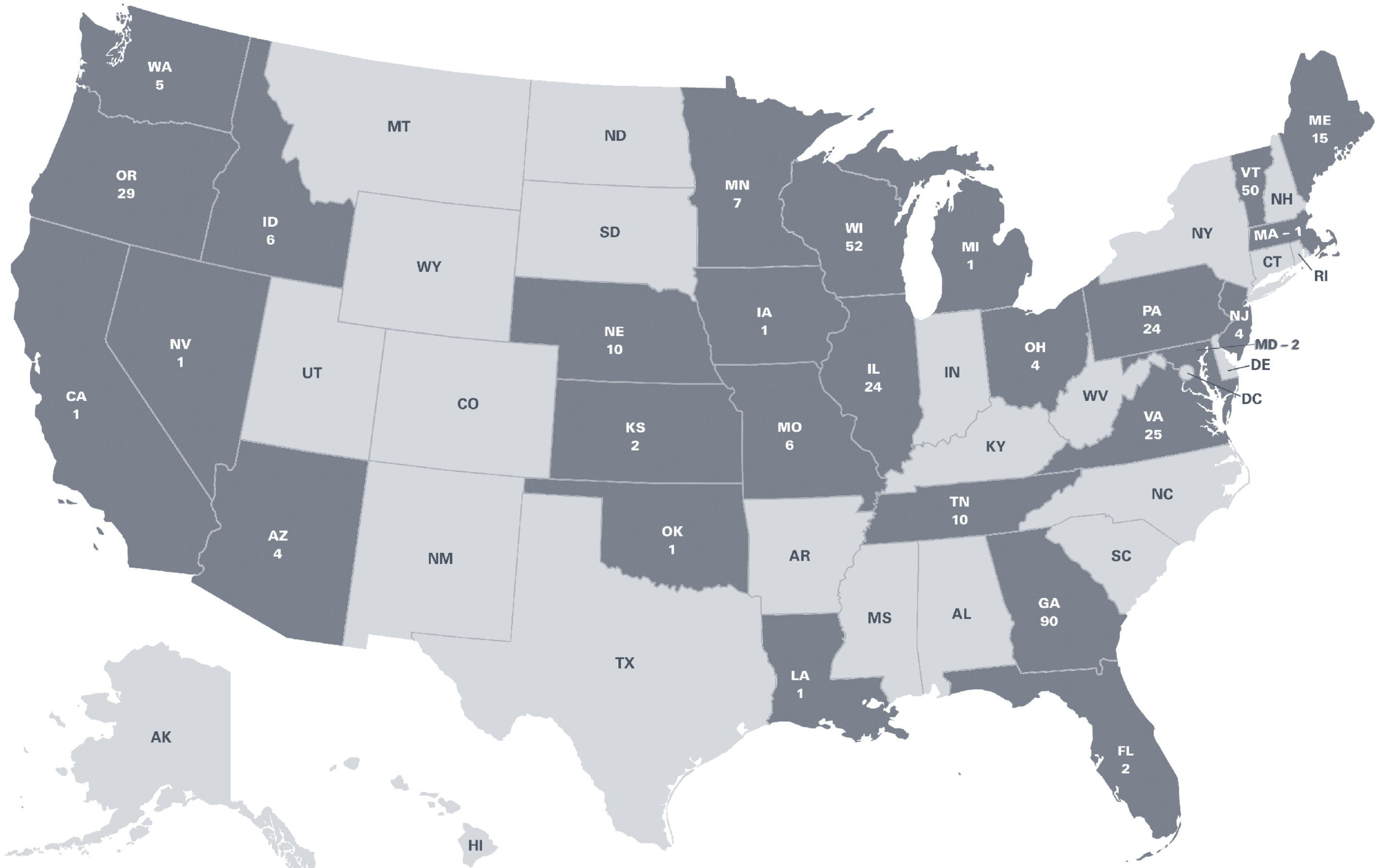


Figure 2. Number of officers or deputies in respondents' agencies

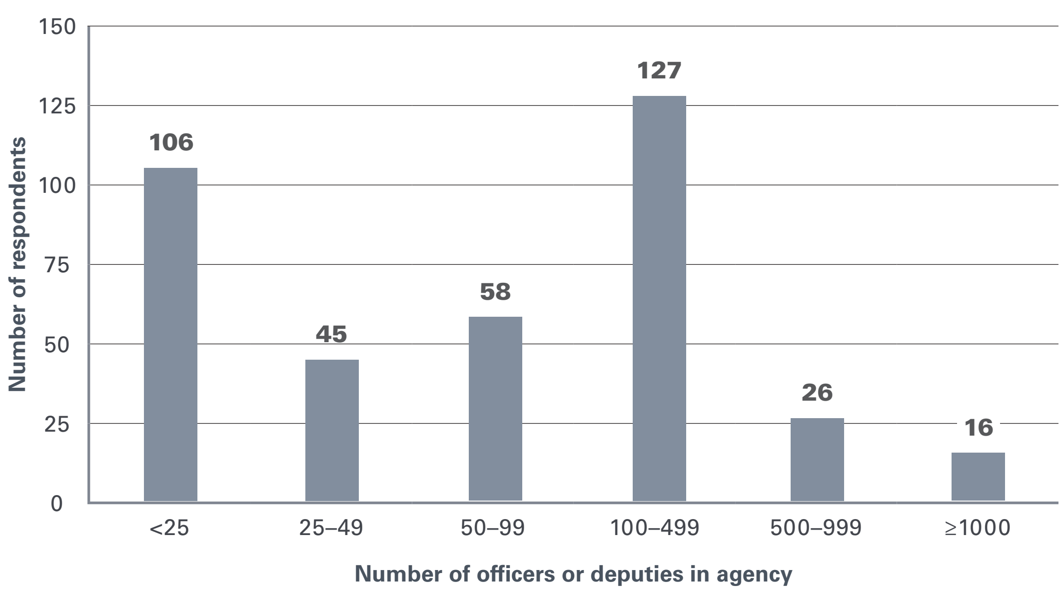
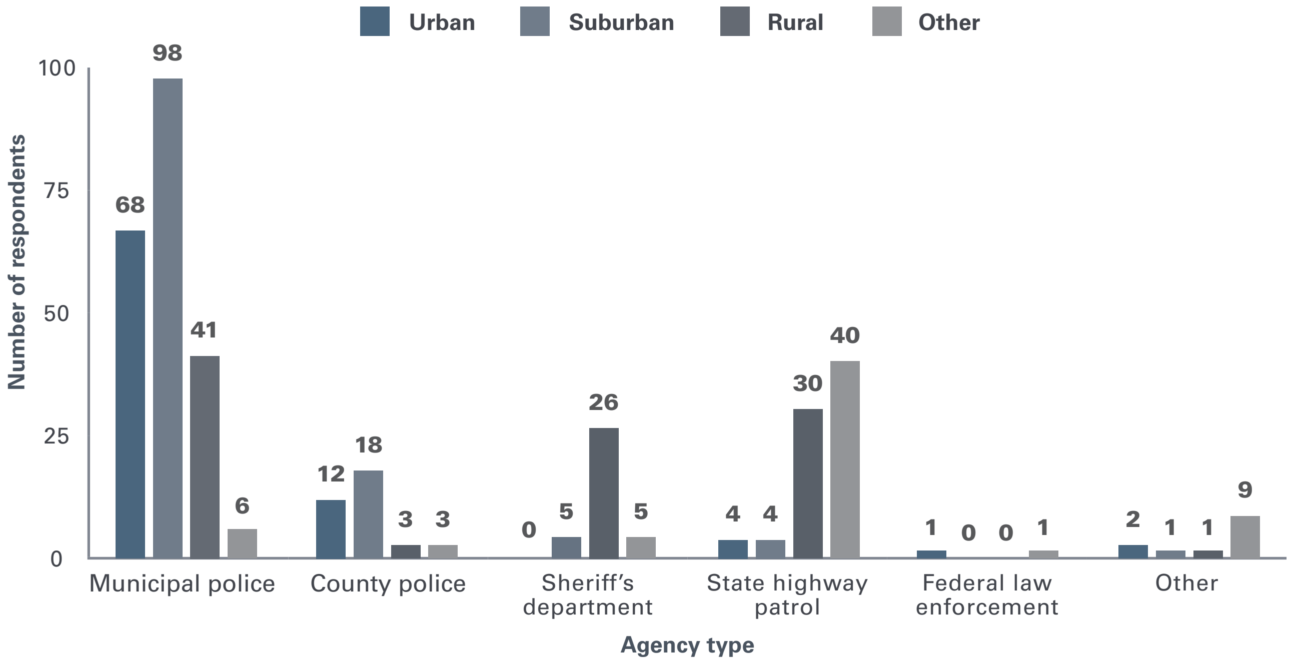


Figure 3. Respondents' agency type and location



Survey qualitative analysis approach

Qualitative analysis centered on participants' answers to a set of questions regarding how their jobs might be affected during use cases such as responding to an incident or traffic stops and checkpoints. The research team analyzed this set of questions in depth using a modified framework methodology (Ritchie and Spencer 1994) to continue building understanding of how to help law enforcement agencies prepare for interactions with level 2+ (L2+) vehicles (i.e., those vehicles equipped with ADAS capable of controlling steering and acceleration and braking under certain conditions). Using an iterative approach, an analyst reduced the data through summarization and synthesis while maintaining the links to the original data, thus allowing for a comprehensive and transparent analysis. The steps of the analysis process are summarized as follows:

1. **Determine focus.** The research team determined that the qualitative analysis would focus on participant responses to the series of open-ended questions regarding awareness of L2+ vehicles in several key use cases (when conducting a traffic stop, responding to an incident, securing a crash scene, and traffic direction and control).
2. **Familiarization.** The analyst compiled the open-ended feedback into a spreadsheet. This process enabled the analyst to become familiar with the data set.
3. **Identify thematic framework.** Based on a review of the data set as well as awareness of the study priorities, the analyst identified key themes that guided data coding and charting. In this case, the themes correlated to the use cases in which law enforcement would likely encounter L2+ vehicles.

4. **Data coding and charting.** Comments related to these themes or use cases were identified in the survey responses and then arranged in spreadsheets (or thematic charts). These thematic charts were further sorted by emerging subthemes and analyzed. Emerging subthemes represented educational needs. While the analysis was carried out by one primary analyst, the outcomes were reviewed by the research team.
5. **Interpretation.** The analyst applied the themes and subthemes detailed in the charts to better understand the information provided by the participants.

SME sessions

A series of focus groups and interviews were conducted for the purpose of exploring key topics from the survey in more depth.

Pilot SME sessions

Six in-person sessions were held at the IACP Conference on Drugs, Alcohol, and Impaired Driving (DAID) in August 2021. Each interview or focus group session included between one and three participants for a total of nine participants. Participants were recruited from attendees at the conference; those expressing interest were provided an information sheet that introduced the study along with consent information (freedom to withdraw, confidentiality, etc.).

Each session was designed to fit the time between conference sessions and lasted approximately 30 minutes. The purpose of these discussions was to allow the team to review the final question protocols for the online SME sessions to ensure the proper discussion would take place and that appropriate insights would be gathered. While the pilot focus groups probed which educational approaches participants preferred, their primary focus was on the interactions to be further explored during the online SME sessions. Key concerns voiced during the pilot sessions included the following:

- Will the vehicle respond appropriately (to traffic direction and control, move over laws, etc.)?
- Would the vehicle yield to the left or the right on an interstate highway during a traffic stop?
- Will people over-rely on the technology? Will drivers be attentive?
- Where will fault lie? Is the vehicle at fault or will the driver be considered impaired?

Online SME sessions

Seventeen online SME sessions were held via teleconference. Each interview or focus group session included between one and six participants for a total of 35 participants. Each session lasted approximately 30 minutes. Participants were recruited for their subject matter expertise in areas such as crash response, crash reporting, crash reconstruction, and law enforcement training. Participants covered different jurisdiction types (e.g., tribal, city; deployment, nondeployment), demographics (e.g., urban, rural), as well as experience (e.g., active-duty officer, trainer, instructor).

Participants learned about the study through the IACP's listservs. A member of the research team reached out via email to individuals who expressed interest in participating, attaching an information sheet that introduced the study along with consent information (freedom to withdraw, confidentiality, etc.). A link to an online poll was provided to identify times that were convenient for participants.

Question route

During each session, participants were guided through a series of questions using a slide presentation while the facilitator took notes. This allowed participants to see their comments during the discussion, ensuring that if the facilitator captured something incorrectly, participants could provide clarification in real time.

The analysis centered around participants' answers to a set of questions about how useful awareness of L2+ vehicle features would be during use cases such as responding to an incident or traffic stops and checkpoints. Consistent with the survey, the research team analyzed this set of questions in depth to continue building understanding of how to help law enforcement agencies prepare for interactions with L2+ vehicles.

SME session qualitative analysis approach

The research team conducted a qualitative analysis of participant responses. To provide comparison with the survey findings, a consistent analysis methodology was used.

Knowledge gap analysis

The findings from the preceding tasks were used to identify where ADS-equipped vehicles, including those in driverless operations, may affect essential policing operations both positively (e.g., improved accuracy of data collected and safety) and negatively (e.g., increased focus on nondriving activities). Further, analysis identified areas where law enforcement's knowledge of ADS-equipped vehicles might be lacking. Questions surrounding these areas were compared to industry-informed documents—such as the SAE International Automated Vehicle Safety Consortium's (AVSC) *Best Practice for First Responder Interactions with Fleet-Managed Automated Driving System-Dedicated Vehicles (*2020), the AVSC's *Best Practice for Data Collection for Automated Driving System-Dedicated Vehicles to Support Event Analysis* (2020), and the Governors Highway Safety Association's (GHSA) *Law Enforcement, First Responder and Crash Investigator Preparation for Automated Vehicle Technology* (Trimble and Terry 2021)—to identify outstanding knowledge gaps between law enforcement and industry. Outstanding knowledge gaps were presented to industry insiders and experts to determine critical areas where it would be beneficial for more information to be shared between law enforcement and ADS developers.

Figure 4. Levels of automation

LEVEL 0

Momentary Driver Assistance | You drive, you monitor

Driver is fully responsible for driving the vehicle while the system provides momentary driving assistance such as warnings, alerts, or emergency safety interventions.

LEVEL 1

Driver Assistance | You drive, you monitor

Driver is fully responsible for driving the vehicle while the system provides continuous assistance with either acceleration/braking OR steering.

LEVEL 2

Additional Driver Assistance | You drive, you monitor

Driver is fully responsible for driving the vehicle while the system provides continuous assistance with both acceleration/braking AND steering.

LEVEL 3

Conditional Automation | System drives, you must be available to take over upon request

System handles all aspects of driving while driver remains available to take over driving if system can no longer operate.

LEVEL 4

High Automation | When engaged, system drives, you ride

When engaged, system is fully responsible for driving tasks within limited service areas. A human driver is not needed to operate the vehicle.

LEVEL 5

Full Automation | When engaged, system drives, you ride

When engaged, system is fully responsible for driving tasks under all conditions and on all roadways. A human driver is not needed to operate the vehicle.

Source: NHTSA 2022a.

Background

THE RAPID ADVANCEMENT OF ADS AND ADAS TECHNOLOGIES has required organizations such as SAE International and the American Association of Motor Vehicle Administrators (AAMVA) to define and clarify industry-wide terms. This publication will adhere to the terms and definitions provided by SAE J3016_201806 *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles* (2018) and SAE J3018_201909 *Safety-Relevant Guidance for On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving System (ADS)-Operated Vehicles* (2019).

ADS are the combination of hardware and software that can perform a dynamic driving task (DDT) on a sustained basis with no human input. The SAE defines six levels of automation ranging from level 0, or no automation, to level 5, or complete automation (SAE International 2021). The National Highway Traffic Safety Administration (NHTSA 2022a) provides the following illustration (figure 4 on page 8) of the levels of automation and the role of the driver.

ADAS consist of technologies currently integrated into vehicles, even those at level 0, and apply to systems that are integrated into vehicles that are level 1 or 2. ADAS include technologies that help the driver with tasks such as parking, blind spot assistance, and lane keeping. ADAS terminology is not as regulated as ADS terminology, and AAMVA has recommended a website maintained by the National Safety Council (mycardoeswhat.org) for clarification on a vehicle's features (National Safety Council 2022). A document released by the American Automobile Association (AAA 2019) provides a guideline for manufacturers and legislators to encourage consistent uses of terminology.

One example of ADAS name variation in this AAA document is adaptive cruise control, which has also been marketed as Smart Cruise Control, Intelligent Cruise Control, Adaptive Cruise Control with Queue Assist, Dynamic Radar Cruise Control, Distronic Plus, and Traffic Aware Cruise Control (AAA 2019). The AAA (2019) noted these name variations and pointed out that there are 20 unique names for adaptive cruise control. Such wide variations in naming common ADAS features can create confusion for users, who may not understand the purpose of the technology, as well as for law enforcement, who may need to understand the technology for the sake of crash reporting or reconstruction.

Automated systems and features are regularly being outfitted to modern vehicles; Parikh, Duhn, and Hourdos (2019) listed and described 34 known applications being integrated or planned for integration into the modern vehicle fleet as of 2019 (table 1). These include applications that have long been part of some vehicle packages like automatic emergency braking (AEB), often referred to as forward collision avoidance. In addition, table 1 includes many applications that have only been prototyped and require an upgrade to surrounding infrastructure to be more generally effective, such as work zone warning, railroad crossing, and intelligent traffic signal systems. Lastly, some applications may require connectivity with other vehicles for the system to be effective, like the Connected-Eco Driving application and Cooperative Adaptive Cruise Control (CACC).

Table 1. Automated vehicle (AV) and connected vehicle (CV) applications

AV/CV Application	Description
Automated assistance in roadwork and congestion	Enables automated driving through a work zone to support driver overload situations, such as driving in narrow lanes, and considers the possibility that lane lines are not accurate. Uses objects such as trucks, beacons, and guide walls for guidance.
Automatic emergency braking (AEB)	Sometimes referred to as forward collision avoidance, AEB brakes when the system foresees imminent collision.
Connected eco-driving	Uses vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication (or both) to provide customized real-time driving advice to drivers (e.g., speeds, optimal acceleration and deceleration profiles) to reduce emissions.
Cooperative adaptive cruise control (CACC)	Dynamically and automatically coordinates cruise control among a string of vehicles to significantly increase traffic throughput.
Cooperative intersection collision avoidance system (CICAS)	V2I strategy to reduce frequency of collisions that occur at signalized and stop-controlled intersections.
Curve speed warning (CSW)	Provides alerts to drivers that a curve may require lower speed.
CV-enabled origin-destination studies	Uses CV technology to monitor the beginning and end trip points to extrapolate the route between.
CV-enabled turning movement and intersection analysis	Uses paths self-reported by vehicles to track turning ratios, delays, or other intersection metrics.
Dynamic speed harmonization (SPD-HARM)	Dynamically adjusts and coordinates maximum appropriate vehicle speeds in response to downstream congestion to maximize traffic throughput.

continued

Table 1. Automated vehicle (AV) and connected vehicle (CV) applications *cont'd*

AV/CV Application	Description
Eco-approach and departure at signalized intersections	Intersection traffic broadcasts current state of signal phasing (red, yellow, or green) and the remaining time in that phase.
High speed automation (HSA)	ADS conducts driving tasks on limited access highways at highway speeds with driver supervision.
Intelligent network flow optimization (INFLO)	A bundle consisting of applications such as queue warning, speed harmonization, ACC, and CACC.
Intelligent traffic signal system	Uses data from V2V and V2I communications to control signals and maximize real-time traffic flow.
Lane keeping	Prevents vehicles from drifting out of a lane.
On-highway platooning	Vehicles have shorter headway (gaps) between one another, and a human can drive the lead vehicle with AVs following in a string.
Oversize vehicle warning (OVW)	Alerts drivers if a vehicle cannot pass through a bridge or tunnel.
Pedestrian in signalized crosswalk warning (transit)	Warns bus operators when pedestrians are in the bus's path.
Probe-based pavement maintenance	Allows a vehicle to automatically report potholes or other pavement anomalies on the road.
Probe-enabled traffic monitoring	Uses communication technology to transmit real-time traffic data between vehicles and infrastructure.
Queue warning (Q-WARN)	Provides the vehicle operator with sufficient warning of impending queue for safe braking, lane changing, or route modification.
Railroad crossing warning (RCW)	Alerts drivers approaching an at-grade railroad crossing if they are in an approaching train's trajectory.
Red light violation warning (RLVW)	Alerts CVs or AVs that current trajectory will result in running a red light, allowing the driver or AV to act.
Reduced speed / work zone warning (RSWZ)	Broadcasts alerts to drivers to reduce speed, change lanes, or stop in a work zone.
Restricted lane warning (RLW)	Provides drivers with travel lane restriction information (e.g., high-occupancy vehicle (HOV) lanes, transit only, or public safety vehicles only)
Smart roadside – smart truck display	Provides hours of service constraints, location and supply of parking, travel conditions, and schedules.
Smart roadside – wireless inspection	Uses roadside sensors to provide identification, hours of service, and sensor data to carriers.
Spot weather impact warning (SWIW)	Warns drivers of local hazardous weather conditions.

continued

Table 1. Automated vehicle (AV) and connected vehicle (CV) applications *cont'd*

AV/CV Application	Description
Stop sign gap assist	Helps vehicles determine if there is adequate time for proceeding through an intersection.
Stop sign violation warning	Helps connected and automated vehicles avoid intersection crashes that result from running a stop sign.
Traffic jam assist (TJA)	ADS conducts driving tasks on limited access highways at slow speeds during congested periods with driver supervision.
Vehicle classification–based traffic studies	Allows sorting of vehicle behavior data by vehicle type for traffic studies.
Warnings about hazards in a work zone	Provides warnings to maintenance personnel within a work zone about potential hazards (e.g., high-speed vehicle entering work zone).
Warnings about upcoming work zone	Provides approaching vehicles with information about work zone activities such as travel lane obstructions, lane closures, lane shifts, speed reductions, or vehicles entering/exiting work zones.
Work zone traveler information	Aggregates work zone traffic data.

Source: Interpreted from Parikh, Duhn, and Hourdos 2019

Present state of the technology

At present, ADS-equipped vehicles are being tested on U.S. roadways. In June 2020, NHTSA established a test tracking tool via the Automated Vehicle Transparency and Engagement for Safe Testing (AV-TEST) initiative that allows anyone to access information as states and companies submit their ADS test data. The information includes an interactive map of where tests are being conducted. Further information is embedded in the map, such as the type of testing activity and the type of vehicle being tested, including the manufacturer and a picture of the test vehicle. The tool also has a breakdown of the different companies cooperating with NHTSA in the AV-TEST program and includes links to written news articles about the AV being tested by each company and all recent updates on testing status (NHTSA 2022b).

While widespread deployment has yet to be realized, ADS integration has spurred action by law enforcement and regulatory bodies to create a framework that can evolve and update along with the technology. In general, the framework should consist of committees dedicated to ADS-equipped vehicles as well as recommended requirements for testing, registering, and developing strategies for reacting to deployment. AAMVA's (2022) *Safe Testing and Deployment of Vehicles Equipped with ADS Guidelines* summarizes recommendations for administrative, vehicle, driver licensing, and law enforcement considerations in the wake of ADS-equipped vehicle integration (detailed in the AVSC Best Practice).

Taxonomy and definitions

One of the biggest issues facing the industry and consumers is the agreed-upon use of terminology and definitions for referring to the types of technologies that make up an ADAS or ADS. In previous years, variations of the advancement in automation have been referred to as driverless vehicles (Colias 2021), self-driving cars (Maki and Sage 2018), and even as robotic cars (Thrun 2010). In 2018 (revised 2021), SAE released *Surface Vehicle Recommended Practice J3016, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-road Motor Vehicles*. Table 2 summarizes the terms most relevant to this publication.

Table 2. Selected terms and definitions

Term	Definition
Automated driving system (ADS)	Hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD, q.v.). The term is used specifically to describe SAE levels 3, 4, or 5.
ADS-dedicated vehicle (ADS-DV)	A vehicle designated to be operated exclusively by a level 4 or 5 ADS for all trips within a given ODD's (q.v.) limitations.
Conventional vehicle	A vehicle designed to be operated by a conventional driver during part or all of every trip.
Driving automation	The performance by hardware or software systems (or both) of part or all of the DDT on a sustained basis.
Driver support feature	A general term for level 1 and level 2 driving automation system features
Driverless operation (of an ADS-equipped vehicle)	Operation of an ADS-equipped vehicle in which either no on-board user is present or on-board users are not drivers or fallback-ready users
[ADS-equipped] Dual-mode vehicle	A type of ADS-equipped vehicle designed for both driverless operation and operation by a conventional driver for complete trips.
Dynamic driving task (DDT)	All the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints.
[DDT] Fallback	The response by the user to either perform the DDT or achieve a minimal risk condition after occurrence of a DDT performance-relevant system failure(s) or upon ODD (q.v.) exit, or the response by an ADS to achieve minimal risk condition given the same circumstances.
Minimal risk condition	A condition to which a user or an ADS may bring a vehicle after performing the DDT fallback to reduce the risk of a crash when a given trip cannot or should not be completed.
[DDT Performance-Relevant] System failure	A malfunction in a driving automation system or other vehicle system that prevents the driving automation system from reliably performing the portion of the DDT on a sustained basis, including the complete DDT, that it would otherwise perform.

Table 2. Selected terms and definitions *cont'd*

continued

Term	Definition
Operational design domain (ODD)	Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including environmental, geographical, and time-of-day restrictions, and the requisite presence or absence of certain traffic or roadway characteristics.
Request to intervene	Notification of an ADS to a fallback-ready user indicating that they should promptly perform the DDT fallback, which may entail resuming manual operation of the vehicle (i.e., becoming a driver again), or achieving a minimal risk condition if the vehicle is not drivable.
[Human] User	A general term referencing the human role in driving automation.
[Human] Driver	A user who performs in real time part or all of the DDT or DDT fallback for a particular vehicle.
[Conventional] Driver	A driver who manually exercises in-vehicle braking, accelerating, steering, and transmission gear selection input devices to operate a vehicle.
Remote driver	A driver who is not seated in a position to manually exercise in-vehicle braking, accelerating, steering, and transmission gear selection input devices (if any) but is otherwise able to operate the vehicle.
Passenger	A user in a vehicle who has no role in the operation of that vehicle.
[DDT] Fallback-ready user	The user of a vehicle equipped with an engaged level 3 ADS feature who is able to operate the vehicle and is receptive to ADS-issued requests to intervene and to evident DDT performance-relevant system failures in the vehicle compelling him or her to perform the DDT fallback.
Driverless operation dispatcher	A user(s) who dispatches an ADS-equipped vehicle(s) in driverless operation.

Source: Adapted from SAE J3016 (SAE International 2018)

Forecasted law enforcement vehicle advancements

It is typical for law enforcement vehicles to come with packages that include conventional ADS and ADAS features. As a result, law enforcement professionals are often familiar with similar systems deployed in civilian vehicles. In some cases, ADS and ADAS features can be used for different purposes for law enforcement (Ford Motor Company 2022a). Police vehicle packages across automotive manufacturers vary, but as an example, a police package brochure from Ford describes how blind side monitoring systems and reverse monitoring cameras can be made "always on" for continuous detection of any activity around the vehicle. In addition, newer models of law enforcement vehicles include AEB and a pre-collision assistive system that alerts the driver to an imminent crash before taking action (Ford Motor Company 2022b). Other features that may be requested or available in a law enforcement vehicle include extended idle modes that allow the vehicle to power the many computers and systems inside the vehicle even after long durations without the vehicle being in motion.

Law Enforcement Interactions

Types of interactions

THE INTERACTIONS THAT LAW ENFORCEMENT HAS with privately owned vehicles will change as ADS-equipped vehicles become more prevalent. In 2018, the Crash Avoidance Metrics Partners (CAMP), LLC's Automation and Public Safety Common Solutions (APSCS) Consortium published a report that defined the types of common interactions first responders (law enforcement, fire and rescue, and EMS) have with vehicles during use cases such as responding to an emergency, conducting a traffic stop, investigating an abandoned vehicle, conducting traffic direction and control, stabilizing or extricating a vehicle, and securing a crash scene. In these use cases, the author defined three different types of interactions: (1) direct, (2) indirect, and (3) informational (Terry et al. 2018). This work was used as the foundation for the AVSC (2024) *Best Practice for First Responder Interactions with Fleet-Managed Automated Driving System-Dedicated Vehicles (ADS-DVs).*

A direct interaction is one where a first responder must make physical contact with another vehicle. This type of interaction is more common for fire and rescue personnel who must access the interior of a vehicle to reach a victim than for law enforcement. Examples for law enforcement include checking the temperature of the hood of a potentially abandoned vehicle (Terry et al. 2021).

An indirect interaction is one where a nonverbal indication or communication occurs using varying modalities. For example, sirens communicate to surrounding vehicles that an emergency vehicle is en route and those vehicles should yield. The use of flashing emergency lights on a vehicle indicates that an emergency vehicle is actively responding to an emergency, regardless of whether it is parked or moving. The use of hand signals or gestures with a traffic wand or flashlight to direct traffic are also indirect interactions. Most indirect interactions are communications initiated by the first responder; however, the term does not discount any communication from the driver to the first responder. An example of an indirect interaction from a driver is eye contact to assure an official conducting manual traffic control that the driver has seen and understood their commands (Terry et al. 2021).

An informational interaction requires the exchange of information from a driver to a first responder. The interaction may only require the first responder to see or read such information as the vehicle make and model, color, and license plate number. Some forms of information, such as licensure, registration, or proof of insurance, are provided by the driver, often through official documentation; others, such as inquiries about the purpose of the interaction or requests for assistance from one party to the other, may be exchanged verbally (Terry et al. 2021).

Of the three interaction types, it is expected that indirect and informational interactions will change the most from conventionally human-operated vehicles to ADS-equipped vehicles. The potential absence of a human driver, the degree of responsibility for the vehicle's actions ascribed to the technology versus to a human driver, and even the ownership of a vehicle (privately owned AV versus fleet-operated AV) are expected to challenge the current protocols of first responders, particularly those of law enforcement (Terry et al. 2021).

Interaction use cases

The AVSC (2024), an SAE program, published the *Best Practice for First Responder Interactions with Fleet-Managed Automated Driving System-Dedicated Vehicles (ADS-DVs)*, a document that leverages the aforementioned research effort led by CAMP (Terry et al. 2018) to form a framework of recommended procedures ADS developers and manufacturers can follow to facilitate first responder interactions on a subset of use cases. That document provides (1) definitions of roles associated with emergency situations and processes, (2) descriptions of interactions (use cases) between first responders and ADS-DVs, (3) recommendations to address those interactions, and (4) recommendations for a First Responder Interaction Plan framework.

The use cases pertaining to law enforcement from the AVSC best practices document include traffic stops, checkpoints, responding to an incident, securing a scene, assisting a motorist, investigating an abandoned vehicle, and traffic direction and control. The best practices document also includes other first responder interactions, such as those of fire and rescue and EMS, as detailed by Terry et al. (2018), as well as recommendations for roadway response services, towing and recovery, ADS-DV fleet operators, and lay people who stop to assist.

Responding to an incident

Multiple types of first responders respond to incidents such as a vehicular crash in an emergency fashion—with higher speeds, priority at intersections, and lights or sirens (or both) engaged. This use case applies to law enforcement, fire and rescue, and EMS as primary respondents but may also apply to towing and recovery vehicles. First responders must navigate through traffic as efficiently and safely as possible, and doing so requires interactions with other vehicles, traditionally through the use not only of flashing emergency lights and sirens to notify nearby vehicles of their presence but also of eye contact and affirmation from drivers that they recognize the emergency vehicles and are preparing an appropriate maneuver such as merging away, stopping, or allowing right of way (Terry et al. 2018).

Securing a scene

Once at an incident, such as a vehicular crash, first responders have a responsibility to ensure oncoming traffic does not become part of the current crash scene by directing traffic via hand signals while also setting up temporary traffic control (TTC) devices, such as cones or flares, to instruct traffic on how to proceed. Terry et al. (2018) detailed the different methods for preventing secondary crashes at a crash scene by each domain. For example, law enforcement may position a vehicle(s) upstream on a shoulder with emergency lights engaged to encourage traffic to merge into a particular lane. Fire and rescue will position their larger vehicles in a travel lane as a crash barrier. Ambulances position themselves as close to the incident as possible. These different methods of interfacing with approaching vehicles require different types of interactions that range from perceiving the situation by recognizing an advanced warning to understanding a new route provided by TTCs and reasoning the purpose for each emergency vehicle's positioning.

In addition to approaching vehicles, the vehicles involved at the scene may need to be disabled, accessed, or moved. An ADS-DV may present its own hazards that are different from those encountered with conventional vehicles, such as electrical power storage, vehicle wiring and routing, fuel tank location, and fuel line locations. First responders should be able to identify an ADS-DV quickly to determine appropriate and safe actions. In addition, first responders will need to identify an ADS-DV in a queue created by an incident to know how to influence or signal its behavior either by using TTCs or contacting a fleet administrator. Documentation pertaining to the vehicle or vehicle owner will need to be readily accessible in the event of a crash.

Traffic direction and control

As mentioned in the prior section, first responders may have to perform manual traffic direction and control at a crash scene and in other circumstances, such as during adverse weather conditions, if automated traffic direction and control devices are malfunctioning, during special events, or during human-made or natural disasters. A traffic direction and control use case typically requires a first responder to interact with other drivers using hand signals, traffic wands, flashlights, whistles, and potentially other types of equipment (Terry et al. 2018).

Therefore, best practice recommendations encourage first responders to signal or otherwise direct an ADS-DV to perform a specific action, such as move in a certain direction, come to a stop, begin to move, and other basic maneuvers (AVSC 2024).

Traffic stop and checkpoint

The most common type of interaction law enforcement officers have with motorists, not just vehicles, is the traffic stop. Generally, a traffic stop use case involves police observing a violation or having some reasonable suspicion that the driver is wanted by the law. Police commence a pull-over action by following behind an offending vehicle and initiating the emergency lighting system. If a vehicle does not pull over within a reasonable time, sirens or other methods of alerting the motorist, such as with a public address (loudspeaker) system, may be used (Gaines and Kappeler 2011; Lakewood 2018; Murgado 2012; Terry et al. 2018).

Checkpoints are operationally similar to traffic stops; however, multiple vehicles in a string are required to stop for an interaction with law enforcement. During these operations, vehicles may be required to lower windows, open trunks, or perform other activities per the direction of law enforcement (Centers for Disease Control and Prevention 2024; FLHSMV 2015a; FLHSMV 2015b; NHTSA 2020).

First responders will need to recognize an ADS-DV to signal it to stop. Afterward, first responders will need to ensure the vehicle will remain stationary unless otherwise indicated. An informational exchange may also be necessary as first responders, most likely police, may require documentation or information regarding ownership. A vehicle may also require additional direction once the interaction is complete to either resume driving or remain stationary.

Parked or unoccupied ADS-DV

The anticipated fleet ownership of ADS-DVs would suggest that an ADS-DV would rarely become abandoned (AVSC 2024). However, inoperable vehicles are common to many roadway shoulders. A vehicle may also be unwittingly parked in an area in need of maintenance, requiring its removal. If police encounter a potentially abandoned vehicle, they will often inspect the vehicle and its surroundings in search of a driver or clues as to why the vehicle may be inoperable (visible damage, flat tire, etc.). In many cases, law enforcement might search beyond the immediate area for someone walking and in need of assistance. The actions of many law enforcement officers in regard to an abandoned vehicle vary by state, jurisdiction, and individual preference for extending assistance or concern (Terry et al. 2018).

The status of a parked ADS-DV may not be immediately evident to first responders, who will need to understand how to safely approach the ADS-DV or contact fleet operators if the vehicle is creating a concern. Therefore, the ability to identify a vehicle's status and understand the best means of approaching the vehicle will help inform law enforcement, and even roadway response teams, of the extent to which an investigation is required (AVSC 2024).

Additional interaction use cases

Interactions between law enforcement and ADS-equipped vehicles are also necessary in other use cases. The previous research evaluated conventional traffic stops; however, there are also escalated versions of traffic stops, sometimes referred to as felony traffic stops. Pursuits, or high-speed pursuits, may be necessary in some situations and require law enforcement to maintain pace with an offender with the goal of bringing them to a safe stop.

Felony or high-risk traffic stops

Felony or high-risk traffic stops, where a stop is initiated because of a warrant or suspicion of felonious activity by a vehicle occupant, differ significantly from a routine traffic stop; however, it is worth noting that a seemingly routine stop can unexpectedly escalate in risk. General orders from the University of California, San Francisco specify that, for their agency, a high-risk traffic stop should be avoided by officers unless (1) they believe the person to be stopped has committed a crime of violence, where a weapon was either used or implied or in which serious injury occurred; (2) they have probable cause to believe, or reasonable suspicion, that a felony has been committed; or (3) they believe that a high-risk stop is necessary for officer and community safety (UCSF Police Department 2019).

In this use case, law enforcement agents are trained not to initiate a stop unless back-up units are available (Plano Police Department 2009) or will be available in an appropriate amount of time (IACP 2018a). Some agencies specify a number of police vehicles to be on-hand at a felonious stop. As an example, the police department of Plano, Texas, specified that four vehicles should be present in such cases in its 2009 policy for high-risk traffic stops (Plano Police Department, 2009). As in a conventional stop, law enforcement will signal the stop and direct the target vehicle to an appropriate location with adequate support units in position (IACP 2018a; Plano Police Department 2009). Police vehicles are prescribed to be positioned according to training guidelines (Plano Police Department 2009); however, those guidelines were not published or available for this literature review. It is assumed that the positioning of the vehicles is done strategically and tactically to prevent the pulled-over vehicle from fleeing the area.

On approaching the pulled-over vehicle, officers are trained to be alert for any suspicious movements or actions of the vehicle operator or passengers. Side mirrors and rear and side windows allow police to observe activities inside the vehicle on approach. As a matter of course, law enforcement may order a passenger out of the vehicle as a precautionary measure even without a suspicion of a safety risk. Similarly, an officer may order passengers back into a stopped vehicle if preferable (IACP 2018b).

If ordered outside of a vehicle, it is recommended that law enforcement not position any occupants or other individuals in front of, between, or behind the stopped vehicles because of the potential of being struck by passing motorists (IACP 2018b).

A search of the vehicle may be called for during a suspicious or felonious stop. Prior to the search, an officer will ask for consent to do so. During the search, an officer may remove cover plates and panels, shift seats, and check compartments of the vehicles, and they are required to return items and assets back to their original position if a search does not yield results (UCSF Police Department 2019).

Pursuits

A pursuit may be necessary if a vehicle does not comply with a pull-over request from law enforcement. Law enforcement will conduct a "balancing test," where a decision is made on whether to pursue a fleeing vehicle based on whether the immediate apprehension of a fleeing suspect is worth the risk of the inherent danger that will be created by the pursuit. The consideration factors involve the speeds and maneuvering practices involved, whether the pursuing officer possesses the skills for a pursuit, and whether the pursuit would create unwarranted danger to the officer or others. The volume of pedestrians and traffic must be taken into consideration as well as weather and road conditions. Sometimes a pursuit may be abandoned if the suspect's identity is clearly established and future apprehension can be accomplished without jeopardizing the safety of the officer or others (Chicago Police Department 2020).

Throughout the course of a pursuit, a marked law enforcement vehicle will have emergency roof lights and sirens activated. If the vehicle is unmarked, high-beam flashing headlights in addition to sirens and any equipped light bars must be activated. A typical pursuit should consist of no more than a primary pursuing vehicle and one secondary vehicle to provide backup. Other units will track the pursuit and its progress but not actively participate (Chicago Police Department 2020).

Many tasks and use cases involved in a pursuit are similar to those of responding to an incident in terms of how other traffic is expected to respond to lights and sirens and yield right of way in addition to overtaking intersections. During a pursuit, unless given a directive, police are generally prohibited from boxing in a fleeing vehicle or forcing a collision. In addition, roadblocks are not an option for stopping a vehicle; however, other devices, such as spike strips for penetrating the tires and slowing a fleeing suspect, may be used if necessary (Chicago Police Department 2020).

When initiating a pursuit, law enforcement will relay the reason for the pursuit (violated laws), location, speed, direction of travel, vehicle description, license plate number (if known), number of occupants, and any other relevant information to a dispatch center. The initiating police unit, typically the one that relays the previously listed information, will be the primary pursuit vehicle unless otherwise directed (Chicago Police Department 2020; IACP 2019). In the event a pursuit exits one jurisdiction and enters another, the original law enforcement units involved in the pursuit will discontinue their pursuit when advised that another agency has taken over. Upon discontinuing the pursuit, the primary unit may continue to proceed upon request (per direction of a supervisor) to the termination point to assist in the investigation (IACP 2019).

Perceived Changes to Law Enforcement Interactions

THIS SECTION documents the changes to interactions associated with ADS-equipped vehicles as perceived by industry and law enforcement.

Industry-perceived changes to interactions

As noted, the AVSC (2024) *Best Practice for First Responder Interactions with Fleet-Managed Automated Driving System-Dedicated Vehicles (ADS-DVs)* provides a summary of interaction themes for each use case based on interaction type (table 3 on page 22). To allow for the identification of knowledge gaps, where possible, law enforcement needs identified through outreach efforts associated with this project have been categorized according to these themes. This comparison allowed the research team to identify areas where law enforcement and industry understanding were incongruous.

Law enforcement–perceived changes to interactions

Law enforcement survey findings

Survey respondents' awareness of ADAS and ADS features

As noted, members of law enforcement were engaged in two primary ways: through (1) an online survey and (2) a series of online SME focus groups and interview sessions. Prior to answering questions about specific use cases, survey respondents were asked to rank their level of familiarity with ADAS features and ADS-equipped vehicles using a scale of 1 *(not at all)* to 5 *(extremely*; figure 5 and table 4 on page 23).

Table 3. Best practices for first responder interactions with fleet-managed ADS-DVs' summary of interaction themes by interaction types and use cases

	Direct interaction				Indirect interaction		Informational interaction						
	Access ADS-DV interior	De-power ADS-DV	Disable ADS-DV	Move ADS-DV from roadway	Approach ADS-DV	Communicate with ADS-DV*	Access required documentation	ADS-DV data integrity	Contact ADS-DV fleet operator	Determine presence of passengers	Identify ADS-DV	Identify ADS-DV owner	Identify ADS-DV related hazards
Motorist assist	x	x	x	x	x	x	x			x	x		x
Parked or unoccupied ADS-DV	x	x	x	x	x	x			x	x	x		x
Responding to an incident						x			x				
Securing a scene	x		x	x	x	x	x	x	x	x	x	x	x
Stabilization and extrication	x	x	x		x					x			x
Traffic direction and control						x			x		x		
Traffic stop and checkpoint					x	x					x	x	

* Communicating with the ADS-DV may include contacting and coordinating with fleet operators.

Source: AVSC 2024

Figure 5. Respondents' mean level of familiarity with advanced driver-assistance systems (ADAS) features

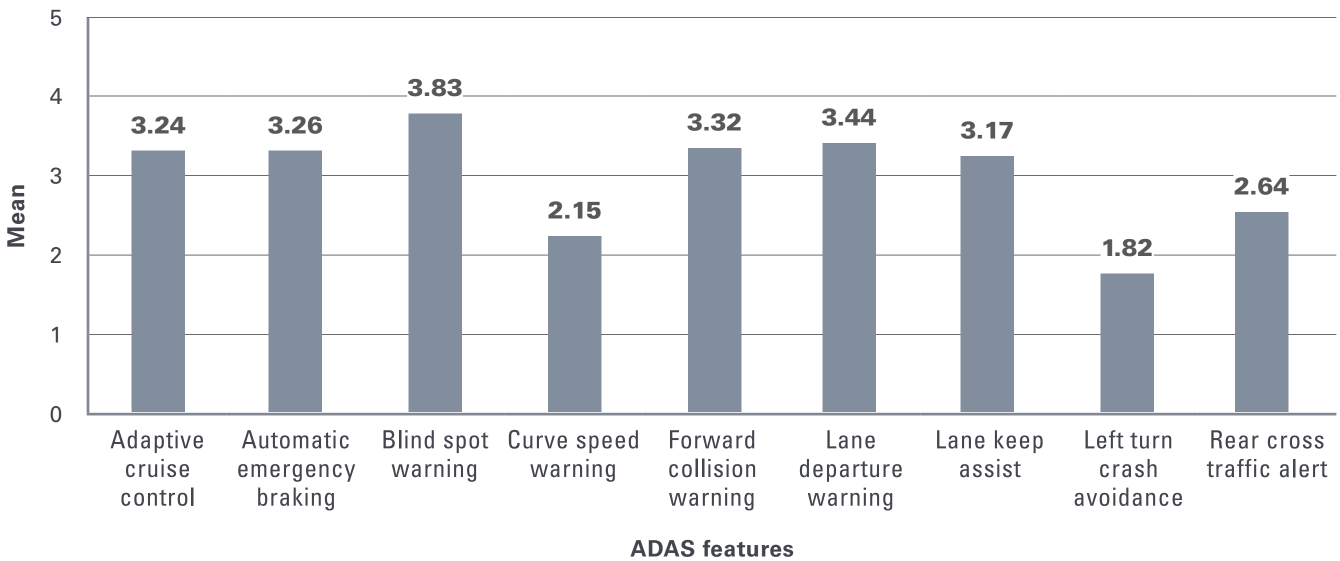


Table 4. Respondents' level of familiarity with ADS-equipped vehicles (n=341)

Response category	Response (n)	Response (%)
Not at all familiar	150	44
Slightly familiar	131	38
Somewhat familiar	39	11
Moderately familiar	16	5
Extremely familiar	5	1

*Totals add up to more than 100% because of rounding.

Respondents were also asked how confident they were that they could identify an ADS-equipped vehicle. The largest number of respondents (136) said they were not at all confident, while only nine respondents said they were extremely confident (see table 5).

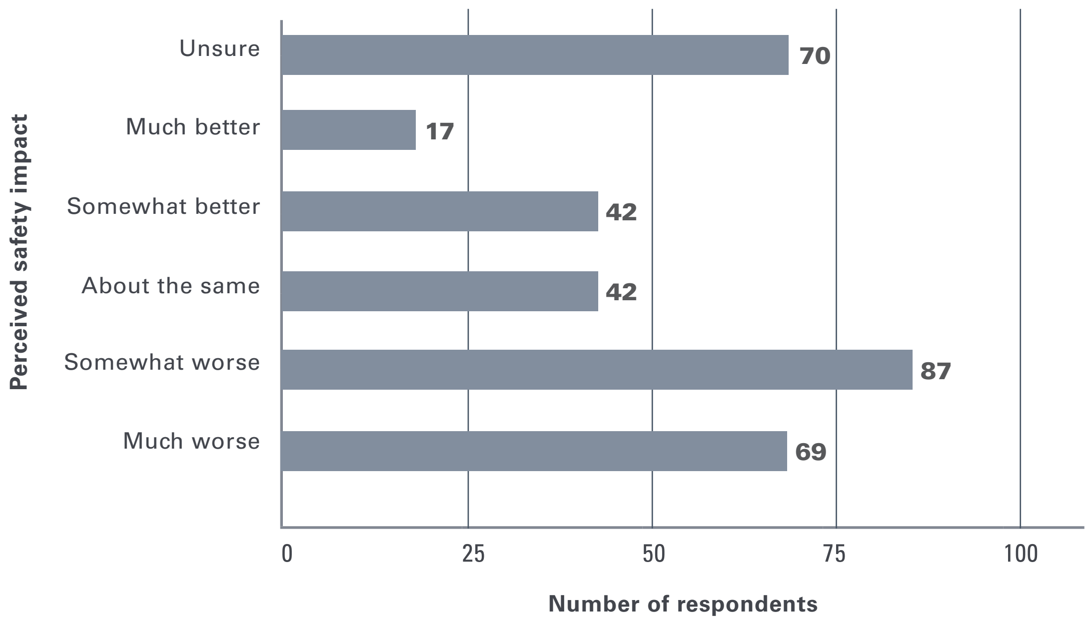
Table 5. SME session participants' confidence ratings (n=341)

Response category	Response (n)	Response (%)*
Not at all confident	136	40
Slightly confident	119	35
Somewhat confident	57	17
Moderately confident	20	6
Extremely confident	9	3

*Totals add up to more than 100% because of rounding.

As to how interacting with an ADS-equipped vehicle without an in-vehicle operator may affect their perceived levels of personal safety compared to human-operated vehicles, respondents' lack of exposure to and experience with both ADAS- and ADS-equipped vehicles became apparent in their feedback. Respondents were significantly more likely to be unsure how their safety may change or have negative perceptions (figure 6).

Figure 6. Respondents' perceptions regarding safety associated with interacting with an ADS-equipped vehicle without an in-vehicle operator



Respondents were also offered an opportunity to share feedback related to specific use cases, and these responses are summarized in tables 6 and 7 on pages 25 and 27. An interaction theme was called out if at least 15 respondents mentioned it. Interaction themes not meeting this threshold were reviewed to ensure that they were captured. For example, within the traffic stops and checkpoints use case, two individuals specifically noted concerns with the AV responding correctly with lane departures or merging lanes. This is a subset of concerns associated with the larger subtheme of questioning whether the AV will pull over, move over, or yield correctly.

Crosscutting survey use case needs

Across use cases, there exists general uncertainty that the AV will respond appropriately. Respondents expressed uncertainty in terms of how to interact with the vehicle, including concerns about officers and pedestrians being detected and avoided. Additional concerns included questions about how to get the vehicle to stop and how to secure the vehicle once it is stopped (e.g., will the vehicle know it is being pulled over? where will it pull over? ADS may not yield). Relatedly, respondents specifically expressed concerns reflecting their lack of trust in the AV responding appropriately. This uncertainty and lack of trust can likely be tied to respondents' limited understanding of and experience with ADAS- and ADS-equipped vehicles.

Table 6 provides a summary of law enforcement needs and corresponding interaction themes. While understanding how to safely interact with the vehicle and how the vehicle will behave do not necessarily map directly to an AVSC best practice interaction theme, the recommended law enforcement interaction plans as a whole should provide this framework of understanding. In the near term, however, general training regarding ADAS and ADS capabilities may be helpful to develop understanding of and trust in these technologies.

Table 6. Survey interaction themes and needs spanning multiple use cases

	Ability to secure the vehicle	Detecting and avoiding law enforcement and pedestrians	Pull over, move over, or yield correctly	Trust the AV to respond appropriately	Understand how the vehicle will behave	Understand how to safely interact with the vehicle
Responding to an incident			†‡BE	CD	CD	CD
Securing a scene	*†‡§ABE			CD	CD	CD
Traffic direction and control	*†‡§ABE	†‡BE		CD	CD	CD
Traffic stop and checkpoint	*†‡§ABE	†‡BE	†‡BE	CD	CD	CD

***** Access ASD-DV interior

† Approach ASD-DV

‡ Communicate with ASD-DV

§ De-power ASD-DV

A Disable ASD-DV

B Move ASD-DV from roadway

C Regarding specific deployments, may be addressed through development of First Responder Interaction Plans, which should include efforts to address the concerns of local authorities and first responder stakeholders

D Near-term training may be beneficial

E No gap identified

Unique survey use case needs

Several unique use case interaction themes were identified and are presented in table 7 on page 27. For the use case "responding to an incident," a unique interaction theme was related to law enforcement's ability to communicate with the ADS-DV. Law enforcement respondents noted concerns regarding the ADS-equipped vehicle's ability to recognize and respond to lights or sirens or emergency equipment more generally. Similarly, when thinking about conducting a traffic stop or checkpoint, respondents voiced concerns regarding the ADS-equipped vehicle pulling over in a safe location (e.g., how the vehicle would know where to pull over or how a safe spot to pull over would be identified). When conducting a traffic stop, additional unique concerns centered around officer safety, with several respondents voicing more specific concerns regarding the potential opportunities that ADS-equipped vehicles may provide drivers and passengers to focus on non–driving related tasks, including preparing themselves to ambush the responding officer. Moving forward, policy discussions may be necessary to address concerns regarding officer safety.

Not unexpectedly, the need associated with conducting traffic direction and control centered around ADS-equipped vehicles' ability to recognize and follow officer directions when presented in a variety of ways, such as hand gestures, flagging, and voice commands. Similarly, in thinking about securing a scene, respondents were concerned about ADS-equipped vehicles' ability to recognize crash or emergency scenes and to avoid them. Further, respondents voiced concerns regarding mechanical issues associated with vehicle operation or equipment issues (e.g., equipment failure, vehicle start and stop, disabling vehicle, damaged electronics, battery problems).

Table 7. Unique survey use case interaction themes and needs

	Ability to respond to lights and sirens	Focus on nondriving tasks (preparing for ambush, distracted, sleeping)	Maintain or ensure officer safety (see and avoid officer)	Mechanical concerns (equipment failure, start/stop, disabling vehicle, damaged electronics, battery problems)	Pull over safely	Recognize and avoid crash or emergency scene	Recognize and follow law enforcement directions (hand gestures, flagging, voice commands)
Responding to an incident	‡G						
Securing a scene				*§BCDG		‡G	
Traffic direction and control							‡G
Traffic stop or checkpoint		†AF	‡E		†‡DG		

***** Access ASD-DV interior

† Approach ASD-DV

‡ Communicate with ASD-DV

§ De-power ASD-DV

A Determine presence of passengers

B Disable ASD-DV

C Identify ASD-DV hazards

D Move ASD-DV from roadway

E Regarding specific deployments, may be addressed through development of First Responder Interaction Plans, which should include efforts to address the concerns of local authorities and first responder stakeholders

F Additional policy discussions may be required to address driver impairment and/or distraction

G No gap identified

Law enforcement SME session findings

SME session participants' awareness of L2+ features

Prior to being asked questions about the use cases, SME session participants were asked questions to gauge their awareness regarding L2+ vehicles and confidence in their ability to identify L2+ vehicles. The first question was *"On a scale of 1 to 5, how aware are you of L2+ vehicles that can operate with lane keep assist (LKA) and adaptive cruise control (ACC) simultaneously?"* The largest number of participants (14 of 35) said they were moderately aware, while only one participant said they were not at all aware (table 8).

Table 8. SME session participants' awareness of L2+ vehicles (n=35)

Response category	Response (n)	Response (%)
Not at all aware	1	3
Slightly aware	6	17
Somewhat aware	9	26
Moderately aware	14	40
Extremely aware	5	14

Participants were also asked, *"On a scale of 1 to 5, how confident are you that you could identify a L2+ vehicle?"* The largest number of participants (12 of 35) said they were not at all confident, while only three participants said they were extremely confident (see table 9).

Table 9. SME session participants' confidence ratings (n=35)

Response category	Response (n)	Response (%)
Not at all confident	12	34
Slightly confident	8	23
Somewhat confident	8	23
Moderately confident	4	11
Extremely confident	3	9

Law enforcement members participating in the SME sessions were asked *"In which of the following use cases would it be most useful to be aware that a vehicle you were interacting with was equipped with L2+ features?"* The rankings provided by participants are found in table 10. Some participants provided more than one response, and in one session two participants did not choose a use case.

Traffic direction and control ranked the highest, followed by traffic stops and checkpoints. The use case participants mentioned least was abandoned or unattended vehicles. It should be noted that some participants ranked responding to an incident as most useful but went on to describe interaction themes more associated with securing a scene when asked why it would be useful. This was taken into consideration during the analysis, though their initial ranking choice was not changed.

Table 10. SME session use case rankings (n=46)

Use case	Count
Abandoned or unattended vehicle	1
Securing the scene	5
Responding to an incident	9
Traffic stops and checkpoints	12
Traffic direction and control	19

After participants provided their ranking, they were asked to explain *"Why would it be useful to be aware that a vehicle contained L2+ features?"* during that use case. They were also asked if there were any other use cases where it would be useful to be aware that a vehicle contained L2+ features. Results from the qualitative analysis are provided in tables 10 and 11 on page 30 per use case and interaction themes.

Crosscutting SME session use case needs

Three interaction themes were mentioned across multiple use cases in the SME sessions: (1) understanding how to safely interact with vehicles with these features, (2) understanding how the vehicles will behave, and (3) officer safety (table 11 on page 30). These crosscutting interaction themes may be due to perceived overlapping among some of the use cases, such as responding to an incident and securing the scene. For instance, officer safety is a crosscutting interaction theme that emerged primarily under traffic direction and control, though it was mentioned under other themes (e.g., securing the scene).

Table 11. SME session use case interaction themes and needs spanning multiple use cases

	Maintain officer safety	Understand how the vehicle will behave	Understand how to interact safely with the vehicle
Responding to an incident	AGK	*ADG	AG
Securing a scene	†‡§ACEF		*†‡§BCDEH
Traffic direction and control	*AD	ADH	*AD
Traffic stop or checkpoint	AD	*§A	

* Crosscutting interaction themes that emerged under a particular use case in three or more sessions are marked to indicate that they were especially prevalent needs for that use case/theme.

† Access ADS-DV interior

‡ Access required documentation

§ Approach ADS-DV

A Communicate with ADS-DV

B De-power ADS-DV

C Disable ADS-DV

D Identify ADS-DV

E Identify ADS-DV related hazards

F Move ADS-DV from roadway

G Regarding specific deployments, may be addressed through development of First Responder Interaction Plans, which should include efforts to address the concerns of local authorities and first responder stakeholders

H Near-term training may be beneficial

K Additional policy discussions may be necessary to address officer safety

SMEs expressed a need to understand how to interact safely with vehicles that have ADS features. This need was mentioned primarily under "securing the scene" and "traffic direction and control." For instance, concerns were raised about how to properly stop or park one of these vehicles to keep a scene safe and how to direct a vehicle with these features (e.g., disable ADS-DV, de-power ADS-DV, move ADS-DV from roadway). Awareness of vehicle features would help law enforcement understand how to safely interact with the vehicle. Examples were given such as knowing the vehicle is electric (e.g., greater shock or fire risk), understanding how to properly disable or park a vehicle to keep a scene safe, and knowing how to interact with a vehicle during traffic direction and control. An officer suggested that in the future, traffic direction may need standard equipment and motions so vehicles can understand it. Again, while understanding how to safely interact with the vehicle and how the vehicle will behave do not necessarily map directly to an AVSC best practice interaction theme, the recommended law enforcement interaction plans as a whole should provide this framework of understanding.

The second crosscutting interaction theme was understanding how the vehicle will behave. This subtheme was primarily an issue under responding to an incident and traffic stops and checkpoints. For instance, under "responding to an incident," participants questioned if the vehicle will recognize an emergency vehicle coming from behind and respond appropriately (e.g., communicating with ADS-DVs). Similarly, participants questioned if the vehicle will pull over and stop appropriately during a traffic stop (e.g., move ADS-DV from roadway). Other participants mentioned the necessity of understanding how the vehicle will respond to an officer pointing in a certain direction to detour traffic and knowing if the vehicle is going to move or stop differently than what officers normally see during a traffic stop.

Officer safety was primarily mentioned under "traffic direction and control" but crosscuts several concerns. Participants used words such as *vulnerable*, *danger*, and *alarming* to describe interacting with these vehicles if the vehicle did not recognize and respond appropriately. Traffic direction and control was a key use case where participants shared concerns about being out in the road interacting with these vehicles. Participants shared concerns about officers being vulnerable standing in the roadway directing traffic if a vehicle does not respond appropriately (e.g., communicating with an ADS-DV) but also about officer safety interacting with an electric vehicle at a scene or with a vehicle during a traffic stop (e.g., identify ADS-related hazards). A few participants shared concerns about higher-level vehicles in which a driver may not be present. As one participant said, if "there's not a person in that [vehicle] or [. . .] ability to influence that vehicle and how it moves, how it stops, how it goes, then that's [a] very dangerous position for somebody out in that roadway to be."

Unique SME session use case needs

Table 12 on page 32 details interaction themes that emerged primarily under one use case and were mentioned in at least three of the 17 sessions. In terms of securing the scene, participants described how knowing a vehicle had these features would inform their approach to gathering information for crash investigations. Being aware that a vehicle is equipped with these features would inform crash investigations by helping officers know what information to gather at a scene to better understand what happened during a crash (e.g., was it driver or vehicle error). As one participant noted, "I just think that my approach to the scene would be different, because I might gather more evidence at the scene as opposed to back at the office regarding the features of the vehicle, and my brain will start spinning of what actually caused this crash? Is it human error versus vehicle error?"

Under “traffic direction and control,” participants voiced concerns about the ability of vehicles to identify an officer in the roadway and respond appropriately to the officer’s presence and direction. They raised concerns about how well a vehicle with these features will identify officers in the roadway and respond to their presence and direction. As one officer commented, “if I’m standing in the roadway, I’d like for that vehicle to know, identify me as a person, and to slow down or stop if I’m in the roadway.”

During discussions of traffic stops and checkpoints, participants discussed the importance of being able to determine if a driver is in control of a vehicle with these features in cases such as a DUI. Participants discussed how these vehicle features may make it harder to identify people who are DUI or may become an issue in DUI cases (e.g., driver was overly relying on the features). A participant pointed out that assessing driver control would be important as evidence in court. They noted, “if you stop someone for driving under the influence, again, what type of feature was the vehicle in? Was the driver actually operating the vehicle? Was he not operating the vehicle? It’s evidence that we could use in court for convictions for those types of incidents.” To help identify ADS-equipped vehicles in the future, policy discussions may focus on more

Table 12. Unique SME session use case interaction themes and needs

	Securing the scene	Traffic direction and control	Traffic stop or checkpoint
Determine driver control and fitness (especially for L2+ vehicles)			*†ACDGH
Inform crash investigations	*†‡BCEF		
Respond to law enforcement		*†ABDE	

***** Access required documentation

† ADS-DV data integrity

‡ Approach ADS-DV

A Contact ADS-DV fleet owner

B Identify ADS-DV

C Identify ADS-DV owner

D Identify ADS-DV fleet operator

E No gap identified

F AVSC Best Practice for Data Collection for ADS-DVs to Support Event Analysis may also be consulted

G Additional policy discussions may be required to improve methods of identifying vehicles in a non-onerous manner

H Additional policy discussions may be required to address driver impairment, fatigue, or distraction convenient methods of identification. For example, during the vehicle licensure process, the issuance of special license plates may alert law enforcement to the potential capabilities of a vehicle. Additional policy discussions may be required to address driver impairment, fatigue, or distraction.

SME session minor themes

A few unique issues emerged in only one or two sessions and are not listed as subthemes in table 11 on page 30 but are included here as they may be important to understanding law enforcement interactions with these vehicles during these use cases. Under "responding to an incident," a few issues emerged such as being able to tell if a driver is having a medical emergency when features are engaged as well as the benefit of dispatch informing a responding officer about what they will be dealing with when they arrive on a scene (e.g., vehicle status, technology). These concerns may be addressed via the following AVSC interaction themes: communicate with ADS-DV, approach ADS-DV, identify ADS-DV, and determine presence of passengers.

Under "traffic direction and control," participants raised concerns about how well vehicles with these features can recognize and respond to an emergency scene. For instance, a participant questioned how these vehicles will respond to a dynamic crash scene where cones, barriers, or flares are deployed quickly. Another participant raised concerns about the identification of pedestrians walking around a scene. Both concerns may be addressed through the AVSC interaction theme "communicate with ADS-DV."

A few different issues emerged under "abandoned or unattended vehicles." Concerns were raised about a dog being left on a hot day in a vehicle that has a feature such as Tesla's dog mode (i.e., a climate control feature that allows drivers to leave their pets in the climate-controlled cabin), an unattended vehicle being hailed remotely and driving off in the middle of an officer investigation, and how to understand upon arriving at a scene if a vehicle is unattended because it was always driverless or because the driver has left it. Again, these concerns may be addressed through AVSC interaction themes communicate with ADS-DV, approach ADS-DV, and determine presence of passengers.

One discussion that emerged under "traffic stops and checkpoints" centered on driver responsibility. A couple of participants discussed how they assume, even with an ADS-equipped vehicle, that a driver needs to be responsible for ensuring the safe operation of the vehicle. One participant gave the example of a driver taking control to pull over safely during a traffic stop or responding to an emergency vehicle trying to pass en route to a scene. Similarly, one participant raised the issue of driver responsibility in terms of driver impairment. They said the issue of driver impairment was a missing use case, that drivers have a duty to ensure that the vehicle is traveling safely. As previously noted, additional policy discussions may be required to address control and fitness.

Summary of knowledge gaps

Survey respondents and SME session participants raised many different questions and concerns. In both the survey and SME sessions, participants expressed uncertainty about how these vehicles will behave and respond toward law enforcement and how law enforcement should interact with these vehicles to remain safe and to keep others safe. Because of the lack of basic understanding regarding ADAS- and ADS-equipped vehicles, it was difficult for individuals to know exactly how and to what extent their interactions would be impacted. Education and training on how to identify vehicles with these features and how to interact with them safely would be beneficial for law enforcement to know what to expect from these vehicles in terms of behavior and response. As one participant commented, "It would be very beneficial as an officer directing traffic to be aware that something is automated and also be at least trained somewhat in what that vehicle may be trying to sense from you to get an idea of what you want it to do. That way, you can communicate with the vehicle systems appropriately."

Key Takeaways

IN AUGUST 2021, the Governors Highway Safety Association (GHSA) released a report examining how law enforcement and other public safety personnel can better prepare for ADS technologies. In response to knowledge gaps identified through outreach conducted with public safety personnel and industry, the report identified the following topics for training (Trimble and Terry 2021):

- 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

The findings associated with this research support these needs. The first responder interaction plans should be developed through collaborative engagement between industry and law enforcement, where appropriate. While this engagement should help to alleviate law enforcement's concerns for how they will interact with specific ADS-DVs in designated operational design domains or deployments, general education to elucidate the difference between the capabilities of ADAS- and ADS-equipped vehicles and the technologies on the road today would help to reduce misunderstandings (e.g., that fully driverless vehicles are commercially available today in the United States). This general education would be beneficial in the near term and should be updated as technologies evolve.

On the assumption that trust in ADAS- and ADS-equipped vehicles will increase with familiarity with those systems, a combination of training should be provided. Ideally, this training would include a brief presentation (either in person or online) and an opportunity to witness first-hand how these vehicles will operate and respond. If a hands-on, interactive demonstration is not possible, realistic videos should be prepared.

To address law enforcement's concerns associated with the identification of ADS-equipped vehicles in the field, consideration of convenient methods of identification may be warranted. While the identification of these vehicles alone would not indicate the mode in which the vehicle was being operated or the features engaged, law enforcement would be able to obtain a better understanding of the vehicle's potential capabilities.

Throughout the survey and SME sessions, law enforcement expressed concerns associated with personal safety. While aspects of law enforcement safety and procedures to ensure safety associated with the operation of ADS-DVs are included in the suggested first responder interaction plans, concerns related to potential ambushes will require additional thought by both law enforcement and industry. In addition, current legislation and policies related to driver control and fitness associated with distraction, impairment, and fatigue may need to be revisited in instances involving ADS-DVs.

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About VTTI

The **VIRGINIA TECH TRANSPORTATION INSTITUTE (VTTI)** is a research institute of Virginia Tech with more than 300 employees dedicated to solving critical transportation challenges from the vehicular, driver, infrastructure, and environmental perspectives. The institute has been at the forefront of transportation research for more than 25 years and houses the largest group of driving safety researchers in the world. VTTI has effected significant change in public policies for driver, passenger, and pedestrian safety. Through specialized research infrastructure, annual sponsored research expenditures of nearly $50 million, and more than 300 active projects, VTTI continues to advance the design of vehicles and infrastructure to increase safety and reduce environmental impacts. Annually, VTTI research supports hundreds of undergraduate and graduate students and generates more than 140 publications.

To facilitate leading-edge research, VTTI employs a range of tools that include the Virginia Smart Roads, the Virginia Automated and Connected Corridors, and custom-made data acquisition systems. These capabilities have earned VTTI an exclusive standing in the transportation research field, making it a renowned option for transportation research, analysis, and development. In 1996, VTTI was designated as one of three Federal Highway Administration/Federal Transit Administration Intelligent Transportation Systems Research Centers of Excellence. VTTI pioneered and continues to be the international leader in naturalistic driving research, which captures driving behavior and outcomes in real-world settings without experimental constraints or bias. Since the institute's first large-scale naturalistic driving study in 2003 (100 cars), VTTI researchers have transformed our understanding of driver behavior and crash causation using naturalistic data. VTTI is also recognized for its leadership in the realm of vehicle automation; since 2001, the institute has conducted more than $200 million worth of research and development related to advanced safety technology, including connected and automated vehicles.

About the COPS Office

The **OFFICE OF COMMUNITY ORIENTED POLICING SERVICES (COPS OFFICE)** is the component of the U.S. Department of Justice responsible for advancing the practice of community policing by the nation's state, local, territorial, and tribal law enforcement agencies through information and grant resources.

Community policing begins with a commitment to building trust and mutual respect between police and communities. It supports public safety by encouraging all stakeholders to work together to address our nation's crime challenges. When police and communities collaborate, they more effectively address underlying issues, change negative behavioral patterns, and allocate resources.

Rather than simply responding to crime, community policing focuses on preventing it through strategic problem-solving approaches based on collaboration. The COPS Office awards grants to hire community policing officers and support the development and testing of innovative policing strategies. COPS Office funding also provides training and technical assistance to community members and local government leaders, as well as all levels of law enforcement.

Since 1994, the COPS Office has been appropriated more than $21 billion to add community policing officers to the nation's streets, enhance crime fighting technology, support crime prevention initiatives, and provide training and technical assistance to help advance community policing. Other achievements include the following:

- To date, the COPS Office has funded the hiring of approximately 140,000 additional officers by more than 13,000 of the nation's 18,000 law enforcement agencies in both small and large jurisdictions.
- More than 800,000 law enforcement personnel, community members, and government leaders have been trained through COPS Office–funded training organizations and the COPS Training Portal.
- Almost 1,000 agencies have received customized advice and peer-led technical assistance through the COPS Office Collaborative Reform Initiative Technical Assistance Center.
- To date, the COPS Office has distributed more than nine million topic-specific publications, training curricula, white papers, and resource CDs and flash drives.

The COPS Office also sponsors conferences, roundtables, and other forums focused on issues critical to law enforcement. COPS Office information resources, covering a wide range of community policing topics such as school and campus safety, violent crime, and officer safety and wellness, can be downloaded via the COPS Office's home page, **https://cops.usdoj.gov**.

Technology has advanced to the point that automatic or autonomous vehi cles—self-driving cars— are a meaningful possibility for the near future. Rather than waiting until a significant number of vehicles are operating without direct human control to assess the public safety implications of such a circumstance, this publication discusses the potential benefits and drawbacks of the increas ing use of this type of technology and outlines the anticipated differences in the ways law enforcement will be called upon to interact with the occupants of vehicles that have been driving themselves.

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