

# Autonomous Road Vehicles and Law Enforcement

## Identifying High-Priority Needs for Law Enforcement Interactions With Autonomous Vehicles Within the Next Five Years

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### EXECUTIVE SUMMARY

Because vehicles with growing degrees of autonomous function are already used on the roads or are promised to arrive soon, law enforcement (LE) needs to consider how to prepare for issues such vehicles will cause or how to contend with actual autonomous vehicles (AVs) in traffic. Traffic stops and investigations involving various types of AVs are occurring in some locations and will become more prevalent over time. There is a need to better understand the problems and opportunities—both technical and legal—that AVs will create for LE in the short term and plan to address them. LE agencies and community leaders in jurisdictions that will be hosting pilot programs of highly autonomous vehicles in the next five years will need to address many of these problems and opportunities soon. For other agencies, communities, bodies supporting LE interests, and AV developers, this instead will be a time for proactive problem-solving and preparation so that law enforcement is not forced into reactive adaptations to a new technology in the future.

On behalf of the National Institute of Justice (NIJ), the Police Executive Research Forum (PERF) and the RAND Corporation convened a workshop to address LE needs related to AVs. The workshop was intended to inform NIJ's science and technology innovation agenda, and it occurred on July 24–25, 2019 in Washington, D.C. The July 24th meeting was held at NIJ offices within the Office of Justice Program headquarters and the July 25th meeting was held at the PERF office. Workshop participants were invited based on consultation with the research literature, federal partners, and known LE agencies that have been engaged with AV interactions (typically as jurisdictions where AV pilot projects are currently under way). This workshop explored specific public safety scenarios involving autonomous road vehicles that have been or will be faced by LE in the short term (i.e., within five years). Discussion focused on four categories of LE interaction: traffic stops, collisions, emergencies (e.g., detours, evacuations), and tangential interactions (e.g.,

### SELECTED PRIORITY NEEDS



#### RESULTS

##### Cybersecurity and AV communication

- Research should be conducted to identify the costs and benefits of various options to identify capabilities and authorization to run in automated mode (e.g., annotation on the electronic registration records, indicator on license plate).
- Research should be conducted to examine the costs and benefits of various options of communicating with AVs running in automated mode (e.g., vehicle-to-vehicle, communication between the light bar and AV).

##### Stakeholder communication and collaboration

- Workshops and ride-alongs should be conducted for law enforcement staff and other agency staff to raise knowledge levels.
- A survey of law enforcement and crash reconstruction experts should be conducted to identify the type and quality of information that would be most useful (and potentially pass this along to standards committees).

##### Standard procedures, guidelines, and training

- Model training and guides for law enforcement should be developed for identifying and interacting with AVs running in automated mode.
- A general description of the kinds of behaviors that law enforcement will expect AVs to be able to perform should be developed that is representative across the United States.

AVs as a source of evidence during an investigation, exclusion zones). Participants were led through the scenarios in a semi-structured discussion.

Following the discussions, experts participated in a ranking exercise to identify the

most-important *needs* (i.e., a problem or opportunity and accompanying solution). Overall, 17 of the identified needs were categorized as high-priority. After the workshop, the authors used their judgment to group these needs into three general categories:

(1) cybersecurity and means of communicating with AVs, their owners, or remote operators; (2) stakeholder communication and collaboration; and (3) standard procedures, guidelines, and training needs for LE interacting with AVs. We discuss the 17 high-priority needs that

emerged through this exercise and provide additional context based on participant discussions. This report is part of an ongoing series of reports on similar workshops facilitated by the Priority Criminal Justice Needs Initiative.

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### WHAT WE FOUND

#### Short-term expectations.

The workshop participants described expectations about the types of AV deployments that could realistically be observed in the next five years. They thought that programs with geofenced deployments of limited-size fleets of highly autonomous vehicles (e.g., ride-share or shuttle programs) are likely in a few cities, although there probably will be few—if any—examples of fleets operating without the requirement (or capability) of having a human driver in the vehicle. Platooning functions for delivery vehicles might become more prevalent. Finally, although some manufacturers have promised to have vehicles with autonomous driving features that do not require a driver (specifically, Level 4 automation) commercially available in the next five years, participants thought

that individual personal use of such vehicles would be very limited in this time frame.

#### Communicating with AVs.

Participants described a variety of needs related to actively and retroactively communicating with AVs. In particular, participants thought that LE needs to have some way of determining when a vehicle is operating autonomously. Vehicles with differing levels of autonomy are going to be on the road, and establishing the participation of a human driver will affect several important issues, such as the procedure for initiating a traffic stop and culpability for driving behavior. Participants also pointed out that many seemingly simple interactions, such as traffic stops, actually can be quite complex, and LE will need a way to securely communicate with AVs. Participants favored

some kind of electronic signal that could be standardized across the industry in collaboration with LE but thought that additional research into solutions was needed.

#### Stakeholder collaboration.

Overall, participants thought that there was a need for increased interaction, communication, and collaboration among LE, AV manufacturers and operators, and affected communities. Stakeholders would benefit from engaging in more-collaborative, proactive problem-solving and preparation rather than reactive thinking. Participants thought that LE would benefit from more real-world knowledge on the capabilities of AVs and manufacturers would benefit from better first-hand knowledge about how their product affects a community from a LE perspective. Moreover, participants envisioned multiple opportuni-

ties for AVs and the data they collect to be used to improve public safety and enhance LE investigations, provided that stakeholders could agree on appropriate protections for privacy and intellectual property.

#### Adapting LE procedures and training.

LE will need to be prepared to adapt training and resources for new circumstances. For good or ill, resources and training devoted to responding to such events as crashes as a result of driving under the influence (DUI) or crash investigations likely will need to change over time. In addition, criminals likely will be innovative in finding ways to use AVs for criminal purposes, such as attacking vehicles with ransomware, using vehicles for privacy invasion, or using them to traffic drugs and people. LE will need to adapt to these changing tactics and scenarios.

## INTRODUCTION

The automobile has transformed society in countless ways since it was first introduced more than a century ago (Hayes, 2011). In recent years, rapid advancements in sensor and computational technologies have been forging the path for a completely new type of automobile with the ability to operate independently, or without a human driver—the AV, which is defined by the National Highway Traffic Safety Administration (NHTSA) as a road vehicle “in which at least some aspects of a safety-critical control function (e.g., steering, acceleration, or braking) occur without direct driver input” (NHTSA, undated-a). The potential benefits of AVs are significant. These benefits include enhanced safety (although this can be hard to define; see Fraade-Blanar et al., 2018), improved traffic flow, more-efficient use of fuel, and greater mobility (Fagnant and Kockelman, 2015). AVs promise to revolutionize the ways in which people and goods move throughout the world.

Although they are not available to private consumers, AVs with higher levels of autonomous functions can be found navigating the streets of several cities. As of 2019, Waymo’s AVs have driven more than 10 million miles (Etherington, 2019). The list of private companies racing to develop AVs is long and includes both tech companies, such as Waymo, Uber, Lyft, and Tesla, and traditional vehicle manufacturers, such as Ford, Volvo, General Motors, BMW, Toyota, and Audi. Many companies have formed strategic partnerships to speed up the process by pooling knowledge and sharing the substantial costs of developing AV systems. A 2017 Brookings Institution report estimated that from 2014 to 2017, more than \$80 billion had been invested in developing AV systems (Kerry and Karsten, 2017). Growing resources for and attention on AV systems, along with the reality that privately owned vehicles with autonomous features can already be found on the roadways, have led many to speculate that fully self-driving cars will be the new norm in the coming years. Several companies promised to make advanced, highly “self-driving” AVs available by the early 2020s (Chandran, 2019; Etherington, 2017; Marshall, 2019; The Nexus, 2017). However, deploying AVs has proved to be a formidable task, and several developers have pushed back their timelines (Davies, 2019; Davies and Marshall, 2019).

As these features develop and have more and more independence from a driver, LE will need to adapt to their new interaction with road vehicles, manufacturers, and drivers (if they are available). That being said, the pace of development suggests that, although some LE agencies will need to interact

and collaborate with AV manufacturers or organizations operating AVs in their jurisdictions, the vast majority of agencies likely will not need to significantly adapt to highly autonomous vehicles in the next five years. Instead, this period is an opportunity for broader, proactive engagement with the challenges and opportunities that AVs will present to LE before most agencies or developers are forced into reactive adaptations. LE agencies, groups representing LE interests, and AV developers have the opportunity to communicate needs and limitations and create anticipatory policies and technologies now, before there are untenable challenges for LE operations or missed opportunities to improve public safety and broader public acceptance of AV technology.

To better understand the challenges and opportunities associated with LE interactions with AVs, the RAND Corporation and the Police Executive Research Forum (PERF), on behalf of the National Institute of Justice (NIJ), convened a two-day workshop with a diverse group of LE practitioners, established researchers, and industry experts to identify high-priority problems and associated needs related to AVs (see the Workshop Participants box for a full list of names and affiliations). The purpose of the workshop was to identify high-priority challenges and potential solutions in the short term (i.e., within the next five years). Additionally, the focus of the workshop was on LE interactions rather than on potential LE use of AVs. During the workshop, we held a semistructured discussion around four scenarios involving AVs that have been or will be faced by LE: (1) traffic stops, (2) collisions, (3) emergen-

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Vehicles with higher-level features represent a potentially dramatic difference from non-AVs or vehicles with lower-level AV features.

cies (e.g., detours, evacuations), and (4) tangential interactions (e.g., AVs as a source of evidence during an investigation, the creation of AV exclusion zones). A review of these scenarios led to the development of three categories of potential challenges and solutions related to LE interaction with AVs: (1) cybersecurity and means of communicating with AVs, their owners, or remote operators; (2) stakeholder communication and collaboration; and (3) standard procedures, guidelines, and training. Following the discussions, experts participated in a ranking exercise to identify the most-important needs.

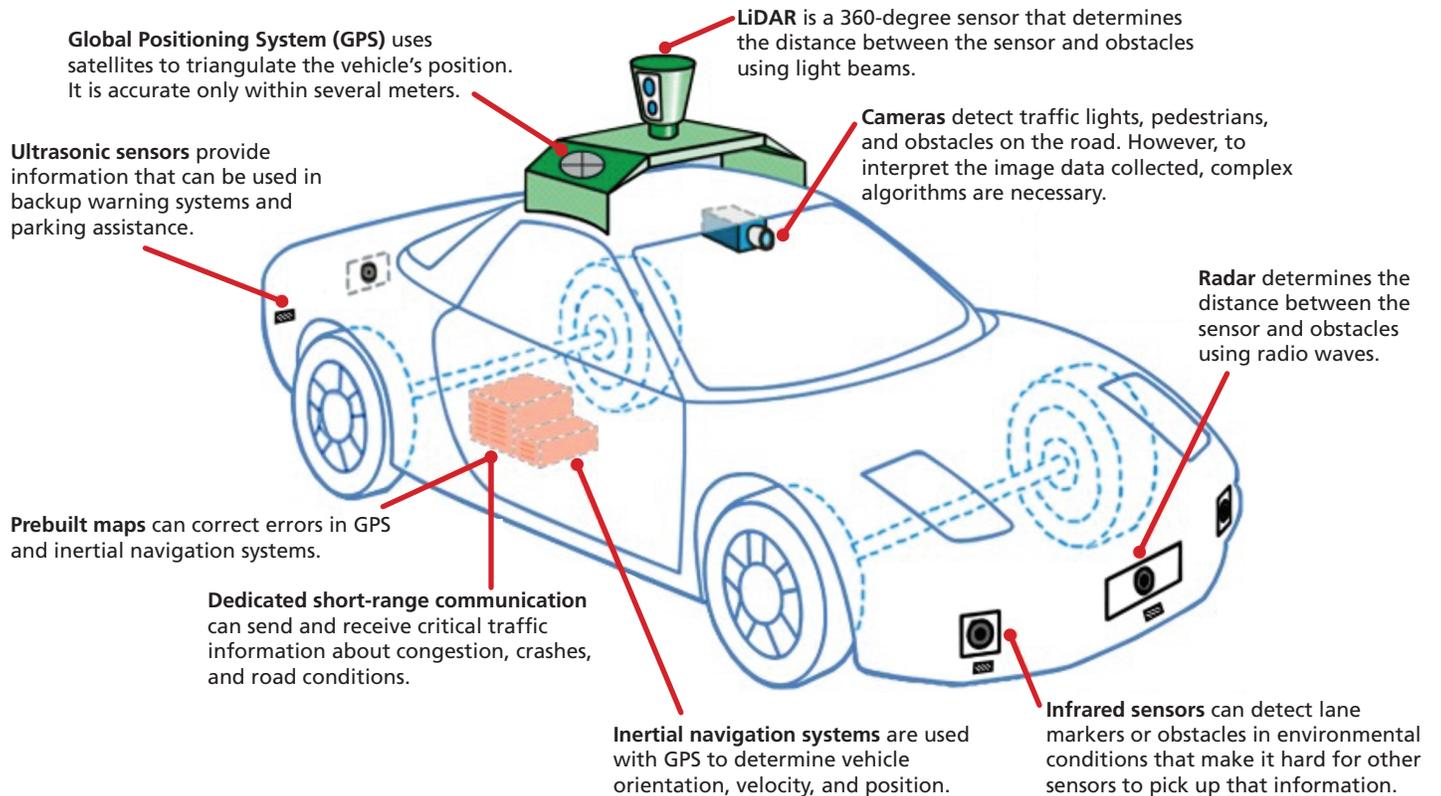
## Functioning and Classification of Autonomous Vehicles

Like human drivers, AVs must collect data, interpret their surroundings, decide on an appropriate course of action, and execute that decision (Campbell et al., 2010). To understand their environment, AVs leverage a robust suite of sensors, such as video cameras and light detection and ranging (LiDAR), radar, ultrasonic, and infrared sensors (see Figure 1). Although the availability of increasingly sophisticated sensors has enabled substantial advances in AV development, their inability to consistently and accurately recognize humans, animals, and other objects presents a significant hurdle to wide-scale deployment (Quain, 2019; Siddiqui, 2019b).

Whether a vehicle is autonomous is a matter of degree rather than a binary quality. In fact, a single vehicle can have multiple features that operate at differing degrees of automation. To classify the degree of autonomy for any given vehicle feature, the Society of Automotive Engineers (SAE) developed a scale describing six levels of automation (see Figure 2), which has been widely accepted by other stakeholders, including the NHSTA (NHTSA, undated-b). Level 0 includes features serving as automated warnings to the driver or temporary assistance. Level 1 and 2 features, which provide more autonomous sophistication as compared with Level 0, are commercially available. Noted examples of Level 1 and 2 automation are automatic emergency braking, lane-centering, and adaptive cruise control functions (Mobileye, undated). Features through Level 2 still require full driver engagement and supervision. Therefore, vehicles with only these levels of features are functionally indistinguishable from non-AVs for the purposes of LE interactions.

Vehicles with higher-level features represent a potentially dramatic difference from non-AVs or vehicles with lower-level AV features. When Level 3–5 features are engaged, the functioning is truly autonomous in that the driver is not control-

**Figure 1. Autonomous Vehicle Sensor Technologies**



SOURCE: Adapted from Center for Sustainable Systems, 2019.

ling the feature. Levels 4 and 5 represent truly autonomous functions, but Level 3 features still require a human driver that is alert, physically able to drive, and technically able to assume control of the vehicle. These higher-level features pose new challenges for LE. A feature is categorized in Levels 3–5 based on the scope of the situations in which it can be used, with Level 3 having the narrowest scope and Level 5 having the widest scope. For example, Level 3 features, such as a traffic jam chauffeur (i.e., a driver can have the vehicle assume control at low speeds during traffic slowdown conditions), can be safely engaged only in limited circumstances and might request that the driver resume full control. Level 4 and 5 features do not have an option for the driver to resume control, and, if the feature in question is acceleration or braking, the vehicle might not have pedals available for any passenger. The key difference between Levels 4 and 5 is that Level 4 features are constrained by conditions (e.g., time and place), while Level 5 features have no such restrictions. Panel members noted that Level 3–5 features typically are limited to specific prototype vehicles or piloting programs rather than available for wide-scale use in the commercially available fleet (see NHTSA, undated-b).

Although Level 5 AV features promise many benefits, including improved traffic flow, increased mobility for less

mobile populations, and increased traffic safety, there are possible drawbacks to consider. For example, some experts noted that these AVs could lead to more vehicle miles traveled (VMT) overall and that these increases might be large enough to offset any benefits realized from improvements in traffic flow or reduced congestion (Millard-Ball, 2019). In addition, more VMT could lead to increased gasoline consumption and higher fossil fuel emissions. This problem could be compounded if people are willing to endure longer commutes in AVs, which would allow occupants to engage in other activities as the vehicle maintains control. However, Anderson et al., 2016, explains that fossil fuel consumption might be offset if AVs stimulate the use of alternative fuels (e.g., by enabling vehicles to locate charging stations between passenger drop-offs and pick-ups) or if safety gains in AVs allow for the production of lighter-weight cars that are more fuel-efficient. Additionally, during the transition to a fully Level 5 fleet, which our experts noted might be many years away, there could be accidents because of the improper use and overestimation of AV features. Level 5 features are not commercially available, but the experts noted incidents in which individuals might interact with lower-level features as if they are at Level 5 and erroneously believe

Figure 2. SAE Levels of Driving Automation



## SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You <b>are</b> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <b>are not</b> driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features			These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
	<ul style="list-style-type: none"> <li>• automatic emergency braking</li> <li>• blind spot warning</li> <li>• lane departure warning</li> </ul>	<ul style="list-style-type: none"> <li>• lane centering OR</li> <li>• adaptive cruise control</li> </ul>	<ul style="list-style-type: none"> <li>• lane centering AND</li> <li>• adaptive cruise control at the same time</li> </ul>	<ul style="list-style-type: none"> <li>• traffic jam chauffeur</li> </ul>	<ul style="list-style-type: none"> <li>• local driverless taxi</li> <li>• pedals/steering wheel may or may not be installed</li> </ul>	<ul style="list-style-type: none"> <li>• same as level 4, but feature can drive everywhere in all conditions</li> </ul>
Example Features						

SOURCE: SAE International, 2018. Used with permission.

that the driver need not be in a condition to reestablish control (Stewart, 2018).

### Methodology

Participants were invited to participate in the workshop based on consultation with the research literature, federal partners, and LE who have been engaged with AV interactions (typically in jurisdictions where AV pilot projects are currently under way). The workshop occurred on July 24–25, 2019, in Washington, D.C., with the July 24th meeting held at NIJ offices within the Office of Justice Program headquarters and the July 25th meeting held at the PERF office.

This workshop explored specific public safety scenarios involving autonomous road vehicles that have occurred or will occur in the short term (i.e., within five years). Our discussion focused on four categories of LE interaction: traffic stops,

collisions, emergencies (e.g. detours, evacuations), and tangential interactions (e.g., AVs as a source of evidence during an investigation, exclusion zones). Participants were led through the scenarios in a semistructured discussion. Following the discussions, experts participated in a ranking exercise to identify the most-important needs. Results were then clustered into top, middle, and bottom tiers through the use of the Delphi method, a technique developed at RAND to elicit expert opinion about well-defined questions in a systematic and structured way (RAND Corporation, undated). Additional details on the methods for structuring the workshop and prioritizing the needs are discussed in the technical appendix.

## RESULTS

During the panel discussion, the workshop participants identified a total of 33 needs. During the prioritization, 17 of these needs were identified as high priority. These 17 top-tier needs are shown in Table 1. Note that, in several cases, when participants identified an issue, they identified multiple potential needs associated with the same issue. Issues that have multiple associated needs are labeled as such in the table. After the prioritization, our analysis of the needs resulted in the creation of three categories into which we sorted needs corresponding to three themes we identified among the needs. These three categories were needs pertaining to (1) cybersecurity and means of communicating with AVs, their owners, or remote operators; (2) stakeholder communication and collaboration; and (3) standard procedures, guidelines, and training.

The categorization of the needs was done based on the authors' subjective judgment after the workshop as a means to facilitate clear discussion based on context from the workshop. We recognize that the categories overlap to a degree, but we nevertheless find this grouping helpful in organizing the discussion of the needs in the next section. Briefly, the rationale for the categories is as follows:

- **Cybersecurity and AV communication** needs are related to the ability to securely and robustly obtain information from or issue instructions to vehicle systems.
- **Stakeholder communication and collaboration** needs are related to fostering greater collaboration and common understanding among LE, communities, AV developers, and other stakeholders.
- **Standard procedures, guidelines, and training** needs are related to developing or implementing standard practices and guidelines.

### Top-Tier Needs

Among the top-tier needs, seven were related to cybersecurity and AV communication; six were related to stakeholder communication and collaboration; and four were related to standard procedures, guidelines, and training.

In the cybersecurity and AV communication category, the expert participants noted the general need for law enforcement to have some way of knowing when an AV is operating in an autonomous mode. LE also needs to be able to check the documentation of an AV (the equivalent of a license and registration request) to facilitate communication with a responsible human in the event of a traffic stop or emergency. Participants also

noted the need for a secure way to direct AVs or communicate intentions to AVs, acknowledging that traffic stop communication can be complex and challenging even with human drivers, and electronic signals of some kind might add vulnerability to cyberattacks. Top-tier needs called for an analysis of cyber risks to AVs and the development of a system for authenticated LE communication with AVs.

Participants noted multiple needs related to the mutual education of LE and other stakeholders in the stakeholder communication and collaboration category. Beyond educating LE about AVs and educating manufacturers and developers on LE procedures, requirements, and technical capabilities, participants noted needs to identify information about AVs that would be valuable to LE and how to share such information. This category included needs for identifying information collected by AVs that could be used to aid in incident response and in postcrash investigations. A need was identified for information-sharing between manufacturers and emergency response organizations that would facilitate vehicle access in emergencies. Finally, participants noted a need for the ability to disseminate information to AVs about regional incidents and events, such as planned closures, to help keep AVs out of situations that would be challenging for them.

Finally, several top-tier needs were related to standard procedures, guidelines, and training. General training is needed for LE to guide interactions with AVs to help in identifying when AVs are operating in autonomous mode or when vehicles are being operated improperly. Participants also noted that LE will need guidelines for dealing with AVs that have been rendered inoperable by some means and developers will need guidelines about how AVs will need to behave in traffic stops.

The expert participants noted the general need for law enforcement to have some way of knowing when an AV is operating in an autonomous mode.

**Table 1. The 17 Top-Tier Needs**

Issue	Need
<b>Cybersecurity and AV communication</b>	
Law enforcement often is unaware of whether a vehicle is capable of or authorized to run in automated mode.	<ul style="list-style-type: none"> <li>• Conduct research to identify the costs and benefits of various options to identify capabilities and authorization to run in automated mode (e.g., annotation on the electronic registration records, indicator on license plate).</li> </ul>
There is a lack of understanding about cyber threats against privately owned or commercial vehicles.	<ul style="list-style-type: none"> <li>• Conduct a threat analysis and risk assessment (TARA) of AVs and design tools to detect cyberattacks and facilitate investigation for law enforcement.</li> </ul>
There is a lack of understanding about cyber threats to law enforcement activities (e.g., traffic stops, identification, remote kill-switch, data exfiltration).	<ul style="list-style-type: none"> <li>• Conduct an analysis of attack models from the perspective of law enforcement agencies.</li> </ul>
Law enforcement often is unaware of whether a vehicle is actually running in automated mode. <sup>a</sup>	<ul style="list-style-type: none"> <li>• Conduct research to examine the costs and benefits of various options of communicating with AVs running in automated mode (e.g., vehicle-to-vehicle, communication between the light bar and AV).</li> </ul>
Using only lights or sound to initiate a traffic stop can leave an AV vulnerable to hacking from unauthorized entities.	<ul style="list-style-type: none"> <li>• Develop a system that allows authenticated agencies to communicate their intentions.</li> </ul>
Law enforcement always needs to have the ability to communicate with something other than a computer (e.g., a responsible human that is the owner or operator).	<ul style="list-style-type: none"> <li>• Develop the equivalent of “license and documentation” that allows law enforcement to check the authorization to operate an AV (and potentially talk with a responsible human).</li> </ul>
Verbal and nonverbal (and voice amplified) communication for traffic stops can be quite complex (e.g., asking vehicles to move into the next traffic lane, asking vehicles to move forward 100 yards, asking vehicles to move into a parking lot, indicating that a traffic stop is complete, or initiating special procedures for felony stops).	<ul style="list-style-type: none"> <li>• Conduct research to identify the most-promising technological solutions that could be used in situations in which verbal communications are used (including assessments of potential adoption rates).</li> </ul>
<b>Stakeholder communication and collaboration</b>	
There is a lack of real-world knowledge among law enforcement and other agencies about AV system capabilities and limitations.	<ul style="list-style-type: none"> <li>• Conduct workshops and ride-alongs for law enforcement staff and other agency staff to raise knowledge levels.</li> </ul>
AV developers have the potential to report relevant information to dispatchers and first responders but lack clarity on what kinds of information would be most useful (e.g., location of incident, number of passengers, airbag deployment, vital signs).	<ul style="list-style-type: none"> <li>• Conduct information-gathering exercises (e.g., workshops and surveys) to develop ideal approaches for conveying information to first responders.</li> </ul>
At present, law enforcement does not have a thorough understanding of the kinds of information that is being collected by AVs and how long it is maintained so that they can request the most appropriate information (for the purposes of crash reconstruction).	<ul style="list-style-type: none"> <li>• Conduct a survey of law enforcement and crash reconstruction experts to identify the type and quality of information that would be most useful (and potentially pass this along to standards committees).</li> </ul>
It is important for law enforcement and other first responders to easily be able to stay current on procedures for accessing an AV (cutting power, towing, etc.).	<ul style="list-style-type: none"> <li>• Develop model web portals that could inform original equipment manufacturers about the kinds of information that law enforcement would benefit from (e.g., law enforcement points of contact, instructional videos on how to cut power).</li> </ul>
There is a need for increased knowledge among AV system developers about how their product affects the community from a law enforcement perspective (e.g., traffic stop procedures, unique aspects of a jurisdiction).	<ul style="list-style-type: none"> <li>• Conduct workshops and ride-alongs for AV system developers to raise knowledge levels.</li> </ul>

Table 1—Continued

Issue	Need
It might be difficult for law enforcement agencies to deal with AVs in areas of planned and unplanned closures (especially AVs that are operating without a capable operator as a backup). <sup>a</sup>	<ul style="list-style-type: none"> <li>Identify best practices for cities and other entities that have information about upcoming closures to share information on events, closures, etc. (This is useful only for planned closures.)</li> </ul>
Standard procedures, guidelines, and training	
Law enforcement often is unaware of whether a vehicle is actually running in automated mode. <sup>a</sup>	<ul style="list-style-type: none"> <li>Develop model training and guides for law enforcement for identifying and interacting with AVs running in automated mode.</li> </ul>
Law enforcement might have to respond to scenarios in which vehicles have been hacked and are not operable (e.g., from ransomware).	<ul style="list-style-type: none"> <li>Develop guides and tools for potential law enforcement responses to AV hacking.</li> </ul>
Law enforcement might have to adapt tactics and procedures when AV technologies are employed incorrectly, improperly, or illegally.	<ul style="list-style-type: none"> <li>Develop a guide containing likely scenarios in which AVs are used illegally and potential solutions.</li> </ul>
There is not a consistent set of “traffic stop” maneuvers that AVs will be expected to perform.	<ul style="list-style-type: none"> <li>Develop a general description of the kinds of behaviors that law enforcement will expect AVs to be able to perform that is representative across the United States.</li> </ul>

<sup>a</sup> Multiple needs were associated with this issue, but the others did not fall in the top tier. See the technical appendix for a complete list of needs.

## DISCUSSION

The goal of the workshop was to probe the knowledge and experience of practitioners, researchers, and industry experts through semistructured discussions to identify important short-term (i.e., in the next five years) needs to prepare LE for widespread interaction with advanced AVs. One of the more notable themes was skepticism of private and commercial AV deployment rates in the short term. Specifically, experts were skeptical that Level 5 features would be ubiquitous on the roadways—or perhaps even available to private and commercial entities—in the short term, despite the promises of many private companies (Siddiqui, 2019a; ABI Research, 2018). As stated by one expert, “Level 5 is a dream, it is speculative . . . because no one is working on a vehicle that can drive itself under *all* conditions yet.” Experts agreed that there are too many outstanding issues facing AV technologies for them to be deployed on a large scale in the short term (Krisher, 2019; Quain, 2019; Siddiqui, 2019b; Ulrich, 2019). One expert commented, “the key to seeing an explosion in safe AVs is learning how they interact with pedestrians, LE, and other AVs. Until we have a good sense of the answer to those questions, there will be limited growth in Level 4 vehicles and above.” However, they believed that it is critical for LE to begin preparing for AVs of all levels now, before the technology catches up.

According to one workshop participant, the short term is likely to see “spot deployments or limited-size AV fleets in a few

cities.” These fleets will number in the hundreds of vehicles and be capable of Level 4 automation. Level 4 AVs will be deployed as part of ride-share programs, typically with a human monitor in the car, or as delivery vehicles (Holley, 2019). Experts expect fewer Level 3 features to be in use, and those that are in use will be deployed in very specific circumstances (e.g., traffic jam chauffeur). Participants noted that there are unique challenges related to determining how and when to safely reengage a driver. In other words, it is easier to develop and implement a feature that is focused wholly on support (Levels 0–2) or a feature where a driver will never need to regain control (Level 4 and 5) rather than a Level 3 feature that attempts to combine support and autonomy. Within the next five years, experts expect to see the greatest increases in the number of Level 2 vehicles on the roadways as issues continue to be resolved at higher levels of automation.

As the number of private and commercial vehicles with automation capabilities swells in the short term, experts expect new public safety–related matters to increase in tandem. This includes, for example, an increase in the number of collisions involving AVs as sensor limitations are discovered. New types of crimes also will surface, such as the use of AVs to transport contraband, the hacking of AV systems to collect drivers’ data (see, for example, Winkelman et al., 2019), crimes committed by ride-sharers against other ride-sharers, and the sale of illicit aftermarket AV components. However, experts expected

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improvements for certain outcomes, such as fewer drunk driving incidents as ride-share programs grow and because private vehicles with autonomous features will have the ability to safely navigate intoxicated occupants home.

As AVs become more common, LE and developers need to plan for and address these issues together. Similar collaboration is evident in jurisdictions where AV pilot testing takes place. Based on these experiences, experts expect to see some LE agencies create dedicated staff positions to serve as specialists on AVs and liaise with private companies operating AV programs in their jurisdictions.

### Policing Scenarios

After identifying the expected state of AV technologies in the short term, experts discussed four scenarios involving expected interactions between LE and AVs: (1) traffic stops, (2) collisions, (3) emergencies (e.g., detours, evacuations), and (4) tangential interactions (e.g., AVs as a source of evidence during an investigation, exclusion zones). The expert panel members noted that the gradual transition toward AVs will lead to many years in which AVs and non-AVs will share the road, meaning that LE will need to continue current methods of policing driver-enabled cars while learning skills and techniques to address AV-related challenges.

Traffic stops are a common—yet complicated—police activity. Given the frequency and the direct impact of AV-capable road vehicles on these interactions, addressing traffic stops likely will be the primary form of LE engagement with such vehicles. Initial questions for the discussion were:

- How do officers determine that they are attempting to conduct a traffic stop with an AV? How do AVs determine that they are being stopped or that officers are responding to an emergency?

- What can or should an AV do when instructed to stop by LE? What laws govern how police and AVs should interact?
- With whom should LE communicate during traffic stops of AVs?
- How do AVs affect probable cause to conduct a traffic stop? Can officers still conduct pretextual stops in search of more-serious crimes?
- Should LE have the ability to override the control of AVs?

Police are expected to respond to traffic collisions as well, both minor collisions with limited property damage and major collisions with potential loss of life. Because AVs might mitigate or eliminate the human factors involved in driving (e.g., fatigue, distraction, inexperience, aggressive driving), collisions could be reduced dramatically. The use of AV features likely will not eliminate collisions entirely for a variety of reasons, including mechanical error, sensor failure, or human misuse of AV features (e.g., using a Level 3 feature as if it were a Level 5 feature). Additionally, experts noted that there might be new collision scenarios, such as an AV not stopping after a minor collision because of sensor failure or a lack of sensitivity to register the collision as an event outside normal road conditions. Initial questions in our discussion on needs for LE interaction in collisions involving AVs were:

- What do officers or first responders need to know or do with a damaged AV, particularly in situations in which AV behavior becomes unpredictable because of failure of electronic components?
- How do officers determine liability between drivers and/or manufacturers?
- What evidentiary information should or can be collected from event data recorders?

- Who owns the data collected by AVs, and what privacy protections should owners or riders expect?

Both emergencies and tangential interactions represent potential deviations from standard programming of AV features. In these situations, the AV will be expected to adapt to LE instruction, which might contradict other communication or programming. Many of the challenges within these scenarios are relevant to traffic stops and collisions, but some of the unique inquiries about these situations were:

- What should LE expectations be for AV responses to adverse conditions (e.g., How will LE address vehicles that need to be cleared or relocated but are not programmed to function in the scenario)?
- Should LE have the ability to override control of AVs to enforce evacuations?
- Can information be requested or recovered from an AV that drove through or near a crime scene?
- How can LE respond if a vehicle finds itself in a zone in which it should not be (e.g., a zone created by a new incident)?

Most of the needs identified by the panel were related to more than one—if not all—of the policing scenarios. Three general themes emerged from the needs generated during these discussions: (1) cybersecurity and AV communication; (2) stakeholder communication and collaboration; and (3) standard procedures, guidelines, and training.

## Cybersecurity and Communicating with Autonomous Vehicles, Owners, and Operators

Issues related to the ability of LE to securely communicate with AVs or their owners and operators were a key theme that emerged from the expert discussion, generating a total of 11 needs, seven of which were top-tier needs. Most of these needs likely would need to be met through engagement and collaboration among AV developers; standards agencies (e.g., (1) SAE and its relevant working groups and (2) a new standards body focused on LE-AV needs); and groups representing broader LE concerns, such as the International Association of Chiefs of Police and the National Sheriffs' Association. Needs for collaboration among these stakeholders are described in more detail in the next section.

To properly engage with AVs, LE must be able to determine whether a vehicle is capable of operating autonomously

and whether it is authorized to do so. This can be challenging because of the diversity of manufacturers, vehicle makes and models, and automation levels. Experts suggested that vehicles could display a physical indicator (e.g., a sticker on the license plate) as a means for LE to quickly assess the capabilities of the AV across key features (e.g., acceleration, steering, braking). These capabilities and authorization also should be integrated into electronic registrations.

LE needs methods to determine whether and when an AV is operating without human control. This is critical from a legal standpoint because how a vehicle is operating could factor into officers' reasonable suspicion and probable cause determinations. For example, an officer might have the legal justification to stop and arrest an intoxicated person who is exercising some control over a vehicle (i.e., functioning at Levels 0 through 3). The same person in a vehicle operating on its own (i.e., Level 4 or 5), however, has committed no crime, and there is no legal justification to stop them. In this example, officers need to know when a vehicle is operating without human control to continue their role in addressing impaired driving and respect the constitutional protections afforded to other drivers. Experts discussed the idea of enabling vehicles to emit an electronic signal that could be read by LE to determine whether a vehicle is operating autonomously. However, it was agreed that additional research would be necessary to identify the best approach for implementing this type of system.

It is essential for LE to be able to communicate directly with AVs and/or their owners or operators in order to conduct traffic stops or convey important information during emergencies (e.g., instructions to pull over and allow emergency vehicles to pass). Participants commented that communications must be able to be conducted nearly instantaneously. For example, it

To properly engage with AVs, LE must be able to determine whether a vehicle is capable of operating autonomously and whether it is authorized to do so.

would not be helpful to require officers to contact a call center to exert control over a vehicle every time a traffic stop must be conducted. This is important within the context of AVs, which might be owned and operated remotely by vehicle manufacturers. At the same time, the experts agreed that it would be important to have a system available for contacting a manufacturer's service representative when necessary. For example, Waymo provides a direct contact to assist first responders in addressing safety issues in the event of emergency or malfunction (Waymo, 2018).

The participants proposed various methods for LE to communicate with an AV, such as requiring the AV to pull over when it recognizes the red and blue flashing lights of a patrol car or the sounds of a siren. However, one potential issue is that cameras on AVs might not be able to discern police lights from other bright lights. Another potential challenge is the variation in how patrol cars are outfitted with light bars and sirens, because of either agency preferences or state regulations. As an alternative, the experts discussed the possibility of enabling patrol cars to transmit an electronic signal to AVs instructing them to pull over. The LE experts explained that traffic stops are incredibly complex interactions that require a robust method of communicating. For example, officers might require a vehicle to stop in a specific location or in a specific way. An officer can easily communicate instructions over a loudspeaker when a human is present and in control of a vehicle, but officers currently do not have a robust way of communicating instructions to an AV. Experts noted that some attempts to develop visual communication systems have been unsuccessful. The experts asserted that digital communication systems should allow for complex interactions to take place and should be standardized across all patrol cars and privately owned AVs. Also, two-way communication should be possible so that vehicles or owners can inform LE if they cannot stop (e.g., because of a broken sensor) or if they need extra time to execute a stop safely. Participants believed that AVs will not benefit from an ability to recognize speech commands or hand gestures because of technological limitations and clear spoofing risks. AVs also will need to have a mechanism in place for determining when they are free to resume driving.

Experts recommended that any communication systems developed for LE to communicate with AVs must be secure. They expressed concern that communication systems might be accessed by nonpolice actors for malicious purposes. There should be a mechanism within these systems to authenticate commands given to AVs to ensure that they are from legiti-

mate LE personnel. This concern also applies to any methods of communication involving lights or sirens, which can be fabricated with commercially available devices by nonpolice actors to pull AVs over.<sup>1</sup> In terms of cybersecurity, participants expressed a need for LE to be able to identify when a vehicle has been attacked. The experts noted that little was known about the cyber threats facing AVs and that additional research is needed on this issue so that LE can prepare accordingly.

## Stakeholder Communication and Collaboration

The stakeholder communication and collaboration contained the most needs. Among the 14 needs identified, six were ranked among the top-tier needs. In addition to LE, the list of stakeholders mentioned during the discussion included individuals and organizations from

- public safety and government (local, state, and federal)
- the automotive industry and other commercial enterprise (e.g., shipping or ride-share)
- technology companies and research institutions
- the insurance industry.

Several needs under this theme revolved around the general lack of knowledge across stakeholders about how AVs will change common LE interactions. Experts agreed that developers need a deeper understanding of common problems officers face in the field and current LE operating procedures so that AVs can be programmed in a way that allows for officers to manage routine interactions (e.g., traffic stops) and nonroutine interactions (e.g., hazardous weather evacuations) with AVs safely and effectively. At the same time, LE needs to be informed of the capabilities and limitations of current AV systems to avoid misconceptions that might result in unrealistic ideas about what can and should be expected of AVs during LE interactions.

To resolve knowledge gaps, participants recommended that stakeholders establish partnerships and open mutual lines of communication to work collaboratively as AVs are being developed. One example of a method to facilitate these relationships was for developers to participate in ride-alongs to gain real-world insight into LE's day-to-day realities. Another example was engaging larger LE participation among associations developing AV-related guidance, such as SAE. The experts stressed the importance of working with various types of LE agencies because it is typical for local and state LE agencies to

respond to entirely different sets of issues and concerns. Experts thought that partnerships could be leveraged to develop standard solutions to problems that LE could easily implement. This is particularly important because the participants identified limited LE agency budgets as a key obstacle that agencies will face when determining how to respond to the introduction of commercial AVs.

Collaboration is needed among LE, developers, and government entities to address issues related to planned and unplanned detours or road closures, such as work zones. A major unresolved question within the industry is whether the prerogative should be given to LE to redirect traffic or if smart infrastructure can offer a more effective solution. Experts were skeptical that AV sensors are sophisticated enough to recognize current LE tools and training for rerouting traffic. Hand signals, for example, are not standardized across agencies. In addition, AVs would have to recognize LE and non-LE personnel who might routinely and legitimately reroute traffic (e.g., construction workers, crossing guards, other emergency personnel, civilians) versus other individuals signaling to a vehicle for illegitimate purposes. Some participants representing LE noted that police likely would not want the ability to completely override AVs. Participants noted that it is doubtful that LE would have the constitutional authority to exercise this ability in all but extreme cases. Moreover, they noted that this would create other issues: LE could incur costs, for example, because of liability for what experts called an “improper shutdown” (i.e., if LE shut down an AV without legal authority as determined after the fact). These costs could be substantial, both financially (via civil lawsuits) and in terms of reputation. Some experts commented that AV capabilities might provide a solution. AV sensors are becoming advanced enough to recognize road signs, and this could prove to be a sufficient device for responding to unplanned routing or closures. When closures or alternative routes are planned for, the use of geofencing to reroute vehicles operating autonomously is a potential solution. Participants suggested establishing a real-time database that can geofence restricted areas in case of major events and communicate this information to AVs, which would be incorporated with a potentially static geofencing database around more-permanent restriction areas, such as government facilities and airports. This type of information is already streamed into existing GPS services.

Another important need under this theme involved understanding the types of data that are collected by AVs, how long such data are maintained, and how LE might legally and

Some participants representing LE noted that police likely would not want the ability to completely override AVs.

technically access those data to carry out investigations. For example, in the case of motor vehicle collisions, vehicle data might be critical for learning about the events leading up to the incident and establishing fault. Currently, LE can retrieve some data from a vehicle’s black box, but accessing black boxes requires special tools that are expensive and might change yearly with new models. In addition, LE often is required to hire specialists to interpret the collected data, which can strain budgets. Experts suggested that the comprehensive sensor data collected by AVs might provide better evidence for crash investigations, although LE might encounter challenges trying to access and use these data. For example, AVs are equipped with numerous types of sensors that collect different kinds of information and are made by a variety of manufacturers; LE might need a wide variety of special tools and training to gather and interpret these data. In addition to these technical issues, participants noted the legal ramifications that would need to be addressed with respect to these data sources, including protection of the constitutional rights of owners and passengers.

Additionally, important data about a roadside event might have been collected by nearby AVs (e.g., an AV driving through a scene in which there was a reported crime having nothing to do with the vehicle itself), and the experts were unsure how this information might be identified and what the implications of obtaining it would be for privacy and constitutional protections. Another challenge with sensor data is that manufacturers and vendors might consider certain data elements to be proprietary and might be reluctant to share them, especially to the extent that sensor data are subject to public records requests. Finally, companies might have an incentive to erase or withhold data in cases in which AVs are the cause of a collision. To overcome these issues, participants suggested legislation ensuring that AV data are preserved and mandates are created for LE access following a collision. To facilitate any such regulatory guidance, common data-formatting standards should

be established, and specific rules should be created to respect privacy considerations and safeguard any intellectual property that might be collected by LE.

Another consideration, one expert explained, is that “data is very difficult to protect, so it is important to know *which* data to protect at all costs.” Participants agreed that it would be useful to develop a package of data elements that are absolutely necessary to have available to properly investigate collisions. Crash reports, crash investigators, and prosecutors were recommended as possible sources for determining which data elements are essential. Any videos captured by cameras embedded on AVs, for example, would be helpful for determining what happened before a collision occurred. Importantly, the experts believed that it would be helpful to resolve the challenges associated with gathering data from black boxes by making AV data easy to access and extract—ideally, “at the push of a button.” It also would be helpful to implement a mechanism to track whether data had been tampered with. Finally, participants suggested some resources be made available to help LE interpret the data and avoid the need to hire an expensive specialist.

Participants also noted that more-prevalent AVs would create new opportunities or challenges related to our understanding of vehicle crashes. Experts noted that AV sensor data could provide a new capability to collect near-miss data. Data on near misses are not currently available, so reliable figures do not exist on crashes that almost happen. From a development perspective, this information could be important for understanding how human intervention might have played a role in averting crashes and bolstering efforts to reduce and prevent future collisions.

Conversely, participants pointed out that the expected reduction in vehicle crashes resulting from increased use of AVs, although it is a decidedly positive outcome, creates new challenges for LE staffing needs and requirements. For example, crash investigations will still be needed, but over time, fewer resources will be dedicated to these investigations. The reduction in the number of overall incidents and diminished

resources might make it increasingly difficult to train skilled investigators. LE increasingly is referring collision investigations to insurance companies, a trend that might accelerate with the introduction of AVs. Alternatively, if AVs become safe enough, incidents and crashes might become rare enough to warrant more-robust investigations by federal authorities, such as those conducted by the National Transportation Safety Board (NTSB) for aviation accidents; in such a circumstance, LE reconstructionists might need significantly more-technical training than they currently have.

AV data might improve the response to collisions by providing LE and emergency services personnel with helpful information about vehicle occupants and the circumstances leading up to a crash. For example, a vehicle might be able to alert first responders that a collision has occurred before a driver, occupant, or witness could. In addition, if the vehicle can convey details about what happened, then first responders can determine what equipment or resources might be necessary at the scene. Other helpful details mentioned by the experts include whether the airbags were deployed, how many occupants are in the vehicle, whether the vehicle is on fire, and whether the vehicle is blocking a roadway. To the extent possible, it would be helpful if emergency services personnel could automatically be provided with biometric or health-related information (e.g., pharmaceutical allergies) that vehicle occupants have elected to disclose in an emergency. Ideally, this information could be transmitted directly from the vehicle to dispatchers to be communicated to first responders.

LE needs to understand how to safely approach and engage with AVs after a crash occurs. In cases in which significant damage occurs, new technologies might present novel fire, electrical, or other hazards to first responders who interact with the vehicle. Experts recommended reviewing U.S. Fire Administration guidelines for interacting with electric and hybrid vehicles as a start for developing guidelines or training programs for interacting with AVs (U.S. Fire Administration, 2019). Some private companies have released LE interaction protocols

AV data might improve the response to collisions by providing LE and emergency services personnel with helpful information about vehicle occupants and the circumstances leading up to a crash.

(Waymo, 2019). Experts also thought it would be valuable for industry to create web portals that are accessible to LE to learn proper procedures for safely handling AVs. Such portals could be used for other purposes, such as submitting warrants for evidence.

### Standard Procedures, Guidelines, and Training

Eight total needs emerged from the general theme of standard procedures, guidelines, and training, four of which were considered high priority. It was clear from the experts' discussion that there is a critical need for standard protocols and training regimes to be established to govern LE interactions with AVs. The lack of standardized guidance and training was a frequent concern throughout the workshop. Although the participants agreed that ubiquitous, highly autonomous vehicles (i.e., Level 4) likely will not be a major concern for LE within the next five years, they also agreed that this is the time to develop training proactively. Experts expressed the need to ensure that all AVs are programmed to behave in the same way in each interaction with first responders so that procedures do not have to change based on the make and model of the car. They explained that procedures must be easy and straightforward to maximize officer safety. Officers must be able to understand how and why a vehicle is behaving in a certain way and what to expect when specific commands are given to ensure that interactions can be conducted in a safe and professional manner.

It is critical for LE and developers to work together to determine how these interactions should occur and what behaviors can be expected of AVs (e.g., windows rolled down, doors unlocked, where registration information is located). Standardization is critical, especially for vehicles that feature higher levels of autonomy. Participants recommended establishing a body or authority to create national standards for the industry to follow. Move-over laws, which exist in all 50 states to protect first responders, would provide a good starting point for crafting national standards for traffic stops and officer safety. In short-term uses of AVs, such as the introduction of small-scale ride-share programs or automated transportation systems, experts stressed that any private company operating AVs should establish standard or preferred means of interacting with LE before their vehicles are put on the roadways.

It was clear from the experts' discussion that there is a critical need for standard protocols and training regimes to be established to govern LE interactions with AVs.

### CONCLUSION

AVs promise to reshape the way people and goods move throughout society. The speed of transformation and widespread AV adoption might be slower than in popular imagination or industry marketing, but specific short-term use cases will create short-term challenges for LE and more-advanced AV features are being developed. Because the driver is a primary conduit through which LE interacts with the public in both routine and emergency encounters, the introduction of AV systems likely will change how these encounters unfold. Our experts agreed that, with rapid advancements in AV technologies expected in the coming years, it is critical to begin preparing LE for a new reality on the roadways now. As we explain in this report, preparing LE includes creating new tools to facilitate communication and investigations involving AVs, along with developing policies and protocols that enable LE to safely manage the myriad routine and nonroutine encounters that might occur on any given day. This also means resolving complicated questions at the intersection of AV behavior and law. For example, is it realistic to expect AVs to obey the letter of the law at all times, or are there specific scenarios where AVs can and should mirror human behavior (e.g., crossing the road median to navigate around barriers in the roadway, such as a downed tree, or stopping briefly in the roadway to drop off passengers)? Experts explained that it will be important for manufacturers to work closely with local and state LE and other key stakeholders to create solutions to these challenges. To inform these efforts, expert participants identified specific, high-priority needs related to cybersecurity and AV communication; stakeholder communication and collaboration; and standard procedures, guidelines, and training. These needs

provide an actionable agenda to better prepare LE for a future in which advanced AV features become commonplace on American roadways.

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## TECHNICAL APPENDIX

In this appendix, we present additional details on the workshop agenda and the process for identifying and prioritizing technology and other needs specific to the workshop identifying research needs for LE and AVs. Through this process, we developed the research agenda that structured the topics presented in the main report. The descriptions in this appendix are adapted from those in previous Priority Criminal Justice Needs Initiative publications and reflect adjustments to the needs identification and prioritization process implemented at this workshop.

### Pre-Workshop Activities

We recruited panel members by identifying knowledgeable individuals through existing professional and social networks (e.g., LinkedIn) and by reviewing literature published on the topic. We then extended invitations to those individuals and provided a brief description of the workshop's focus areas.

In advance of the workshop, panelists were provided an opportunity to identify the issues and topics that they felt would be important to discuss during the workshop. We structured the workshop agenda and discussion as shown in

Table A.1 based on a comprehensive literature review and input from the workshop participants.

### Identification and Prioritization of Needs

During the workshop, we asked the participants to discuss the challenges that they or the practitioners they work with face. We also ask them to identify areas where additional research and development investment could help alleviate the challenges. During these discussions, participants suggested additional areas that are potentially worthy of research or investment. Participants also considered whether there were areas that were not included in the existing list and suggested new ones. Although the process of expert elicitation we describe was designed to gather unbiased, representative results from experts and practitioners in the field, there are several limitations that could affect the findings. The process typically elicits opinions from a relatively small group of experts. As a result, although we attempted to make the group as representative as possible of different disciplines, perspectives, and geographic regions, the final output of the workshop likely will be significantly influenced by the specific group of experts invited to participate. It is possible that the findings from the workshop would vary were a different group of experts selected. Moreover, although the discussion moderators made every effort to act as neutral parties when eliciting opinions from the collected experts, the background and experience of the moderators had the potential to influence the questions they posed to the group and how

**Table A.1. Workshop Agenda**

Day 1	Day 2
Welcome and Introductions	Summary of Day 1 and Overview of Agenda for Day 2
Initial Discussion of Workshop Functions and Objectives	Other Issues
Use Cases: Normal Interactions	Review and Final Brainstorming Session
<ul style="list-style-type: none"> <li>Traffic Stops</li> <li>Accidents</li> </ul>	Final Needs Prioritization
Use Cases: Normal Interactions	Panel Review and Next Steps
<ul style="list-style-type: none"> <li>Detours and Work Zones</li> <li>Evacuations</li> </ul>	
Use Cases: Tangential Interactions	
<ul style="list-style-type: none"> <li>AVs as a Source of Evidence in Nontraffic Investigations</li> <li>Use of Exclusion Zones (i.e., weight limits, height restrictions, hazardous transport routes)</li> </ul>	
Review Key Benefits and Challenges Identified During Day 1, Prioritize Discussion for Day 2	

they phrased those questions. This also could introduce bias that could influence the findings.

To develop and prioritize a list of technology and policy issues that are likely to benefit from research and investment, we followed a process similar to one that has been used in previous Priority Criminal Justice Needs Initiative workshops (see, for example, Jackson et al., 2015; Jackson et al., 2016, and references therein). The needs were prioritized using a variation of the Delphi Method, a technique developed at RAND to elicit expert opinion about well-defined questions in a systematic and structured way (RAND Corporation, undated). Participants discussed and refined problems and identified potential solutions (or *needs*) that could address each problem. In addition, needs could be framed in response to opportunities to improve performance by adopting or adapting a new approach or practice (e.g., applying a new technology or tool in the sector that had not been used before).

At the end of the discussion of each topic, participants were given an opportunity to review and revise the list of problems and opportunities they had identified. The participants' combined lists for each topic were displayed one by one in the front of the room using Microsoft PowerPoint slides that were edited in real time to incorporate participant revisions and comments.

Once the panel agreed on the wording of each slide, we asked them to anonymously vote using a handheld device (specifically, the ResponseCard RF LCD from Turning Technologies). Each participant was asked to individually score each problem or opportunity and its associated needs using a 1–9 scale for two dimensions: importance and probability of success.

For the *importance* dimension, participants were instructed that 1 was a low score and 9 was a high score. Participants were told to score a need's importance with a 1 if it would have little or no impact on the problem and with a 9 if it would reduce the impact of the problem by 20 percent or more. Anchoring the scale with percentage improvements in the need's performance is intended to help make rating values more comparable from participant to participant.

For the *probability of success* dimension, participants were instructed to treat the 1–9 scale as a percentage chance that the need could be met and broadly implemented successfully. That is, they could assign the need's chance of success between 10 percent (i.e., a rating of 1) and 90 percent (i.e., a rating of 9). This dimension was intended to include not only technical concerns (i.e., whether the need would be hard to meet) but also the effect of factors that might lead LE to not adopt the new technology, policy, or practice even if it was developed. Such

factors could include, for example, cost, staffing concerns, and societal concerns.

After the participants rated the needs displayed on a particular slide (i.e., for either importance or probability of success), we displayed a histogram-style summary of participant responses. If there was significant disagreement among the panel (the degree of disagreement was determined by the research team's visual inspection of the histogram), the participants were asked to discuss or explain their votes at one end of the spectrum or the other. If a second round of discussion occurred, participants were given an opportunity to adjust their ratings on the same question. This second-round rating was optional, and any rating submitted by a participant would replace their first-round rating. This process was repeated for each question and dimension at the end of each topic area. Figure A.1 shows an example of a slide on the importance dimension, with related issue, need, and histogram. Figure A.2 shows a slide on the probability of success dimension.

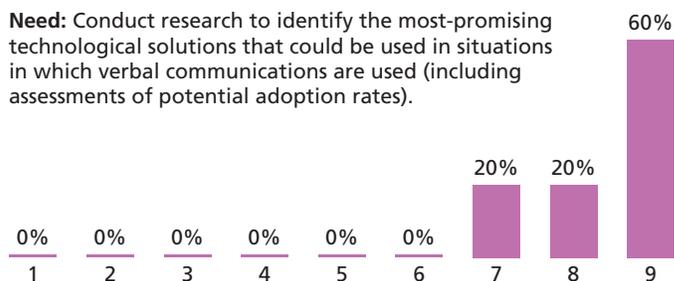
Once the participants had completed this rating process for all topic areas, we put the needs into a single prioritized list. We ordered the list by calculating an expected value using the method outlined in Jackson et al., 2016. For each need, we multiplied the final (second-round) ratings for importance and probability of success to produce an expected value. We then calculated the median of that product across all of the respondents and used that as the group's collective expected value score for the need.

### Figure A.1. Example Slide for Rating the Importance of a Need

#### 6a. How *important* is it to solve this problem?

**Issue:** Verbal and nonverbal (and voice-amplified) communication for traffic stops can be quite complex (e.g., asking vehicles to move into the next traffic lane, asking vehicles to move forward 100 yards, asking vehicles to move into a parking lot, indicating that a traffic stop is complete, or initiating special procedures for felony stops).

**Need:** Conduct research to identify the most-promising technological solutions that could be used in situations in which verbal communications are used (including assessments of potential adoption rates).



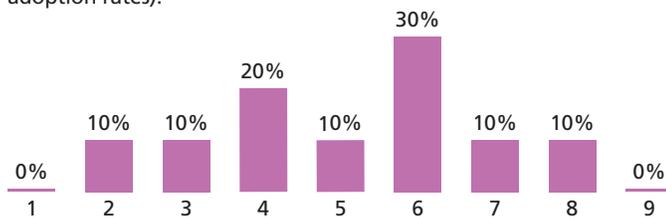
NOTE: Percentages on each question did not always sum to 100 percent because of rounding and variation in the number of participants who voted on each need.

## Figure A.2. Example Slide for Rating the Probability of Success of a Need

### 6b. What is the *probability of success* for this solution?

**Issue:** Verbal and nonverbal (and voice-amplified) communication for traffic stops can be quite complex (e.g., asking vehicles to move into the next traffic lane, asking vehicles to move forward 100 yards, asking vehicles to move into a parking lot, indicating that a traffic stop is complete, or initiating special procedures for felony stops).

**Need:** Conduct research to identify the most-promising technological solutions that could be used in situations in which verbal communications are used (including assessments of potential adoption rates).



NOTE: Percentages on each question did not always sum to 100 percent because of rounding and variation in the number of participants who voted on each need.

We clustered the resulting expected value scores into three tiers using a hierarchical clustering algorithm. The algorithm we used was the “ward.D” spherical algorithm from the “stats” library in the R statistical package, version 3.5. We chose this algorithm to minimize within-cluster variance when determining the breaks between tiers. The choice of three tiers is arbitrary but was done in part to remain consistent across the set of technology workshops we have conducted for NIJ. Also, the choice of three tiers represents a manageable system for policymakers. Specifically, the top-tier needs are the priorities that should be the primary policymaking focus, the middle-tier needs should be examined closely, and the bottom-tier needs are probably not worth much attention in the short term (unless, for example, they can be addressed with existing technology or approaches that can be readily and cheaply adapted to the identified need).

Because the participants initially rated the needs one topic area at a time, we gave them an opportunity at the end of the workshop to review and weigh in on the tiered list of all identified needs. The intention of this step was to let the panel members see the needs in the context of the other tiered needs and allow them to consider whether there were some that appeared too high or low relative to the others. To collect these assessments, we printed the entire tiered list and distributed it to the participants. This step allowed the participants to see all of the ranked needs collected across the day-and-a-half workshop, providing a top-level view that is complementary to the

rankings provided session by session. Participants were then asked to examine where each of the needs landed on the overall tiered list and whether this ordering was appropriate or needed fine-tuning. Participants had the option to indicate whether each problem and need pairing should be voted up or down on the list. An example of this form is provided in Table A.2.

We then tallied the participants’ third-round responses and applied those votes to produce a final list of prioritized and tiered needs. To adjust the expected values using the up and down votes from the third round of prioritization, we implemented a method equivalent to the one we used in previous work (Hollywood et al., 2016). Specifically, if every panel member voted “up” for a need that was at the bottom of the list, then the collective effect of those votes should be to move the need to the top. (The opposite would happen if every panelist voted “down” for a need that was at the top of the list.) To determine the point value of a single vote, we divided the full range of expected values by the number of participants voting.

To prevent the (somewhat rare) situation in which small numbers of votes have an unintended outsized impact—for example, when some or all of the needs in one tier have the same or very similar expected values—we also set a threshold that at least 25 percent of the workshop participants must have voted on that need (and then rounding to the nearest full participant). For this workshop, there were nine participants, so for any votes to have an effect, at least three participants would have had to have voted to move the need up or down.

After applying the up and down vote points to the second round expected values, we compared the modified scores with the boundary values for the tiers to see whether the change was enough to move any needs up or down in the prioritization. (Note that there were gaps between these boundaries, so some of the modified expected values could fall in between tiers. See Figure A.3.) As with prior work, we set a higher bar for a need to move up or down two tiers (from Tier 1 to Tier 3, or vice versa) than for a need to move to the tier immediately above or below. Specifically, a need could *increase by one tier* if its modified expected value was higher than the highest expected value score in its initial tier. And a need could *decrease by one tier* if its modified expected value was lower than the lowest expected value in its initial tier. However, *to increase or decrease by two tiers* (possible only for needs that started in Tier 1 or Tier 3), the score had to increase or decrease by an amount that fully placed the need into the range two tiers away. For example, for a Tier 3 need to jump to Tier 1, its expected value score had to fall within the boundaries of Tier 1, not just within the gap

Table A.2. Example of the Delphi Round 3 Voting Form

Question	Tier	Vote Up	Vote Down
Tier 1			
<b>Issue:</b> There is a lack of understanding about cyber threats against privately owned or commercial vehicles. <b>Need:</b> Conduct a threat analysis and risk assessment (TARA) of AVs and design tools to detect cyberattacks and facilitate investigation for law enforcement.	1		
<b>Issue:</b> Law enforcement might have to respond to scenarios in which vehicles have been hacked and are not operable (e.g., from ransomware). <b>Need:</b> Develop guides and tools for potential law enforcement responses to AV hacking.	1		
Tier 2			
<b>Issue:</b> Law enforcement can be unaware of the companies and types of AVs that are operating within their jurisdictions. <b>Need:</b> Develop a regionally centralized data store where this kind of information can be shared.	2		
<b>Issue:</b> There are a variety of types of data that agencies need to extract or request to assess the behavior of a vehicle (e.g., throttle, braking, and steering commands, objects detected, camera views). <b>Need:</b> Develop a set of reasonable practices, questions, and/or model subpoenas that would help law enforcement agencies.	2		
Tier 3			
<b>Issue:</b> It is difficult for AVs to determine the differences between accepted common practices and the letter of the law so that traffic flow and safety are not adversely affected (e.g., short-term double parking, crossing a double yellow line to avoid an obstruction). <b>Need:</b> Conduct information-gathering exercises (e.g., workshops and ride-alongs) to examine common patterns and practices among human drivers that are officially illegal but where officers might exercise discretion (and assess the implications of such practices).	3		
<b>Issue:</b> When law enforcement agencies need to rely on manufacturers or operating companies to obtain the data needed to investigate a crash, there are potential Fifth Amendment (i.e., right not to self-incriminate) issues. <b>Need:</b> Conduct research to identify the breadth and depth (scope) of the problem.	3		

NOTE: Shaded cells indicate that up or down votes were not possible (e.g., Tier 1 is the top tier, so it was impossible to upvote items in that tier).

between Tier 1 and Tier 2. See Figure A.3, which illustrates the greater score change required for a need to move two tiers (one need on the far right of the figure) compared with one tier (all other examples shown).

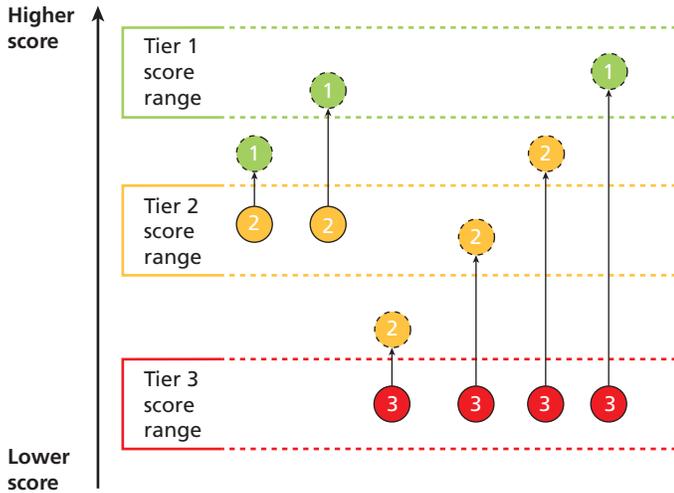
Applying these decision rules to integrate the participants' third-round inputs into the final tiering of needs resulted in numerical separations between tiers that were less clear than the separations that resulted when we used the clustering algorithm in the initial tiering. This can occur because, for example, when the final expected value score for a need that was originally in Tier 3 falls just below the boundary value for Tier 1, that need's final score could be higher than that of some other needs in the item's new tier (Tier 2). See Figure A.4, which shows the distribution of the needs by expected value score after the second-round rating process and then after the third-round voting process.

As a result of the third round of voting, 24 needs did not change position, seven needs rose by one tier, and two needs fell by a tier. No needs moved two tiers. The output from this process became the final ranking of the panel's prioritized results.

The complete list of identified needs is shown in Table A.3, and the needs are sorted by tier and theme. Of the 33 identified needs,

- 11 were related to cybersecurity and AV communication (seven of which were top-tier)
- 14 were related to stakeholder communication and collaboration (six of which were top-tier)
- eight were related to standard procedures, guidelines, and training (four of which were top-tier).

**Figure A.3. Illustration of How a Need's Increase in Expected Value Might Result in Its Movement Across Tier Boundaries**



NOTE: Each example need's original tier is shown by a circle with a solid border (the two needs starting in Tier 2 and the four needs starting in Tier 3). Each need's new tier after the third-round score adjustment is shown by the connected circle with a dotted border.

**Figure A.4. Distribution of the Tiered Needs Following Rounds 2 and 3**

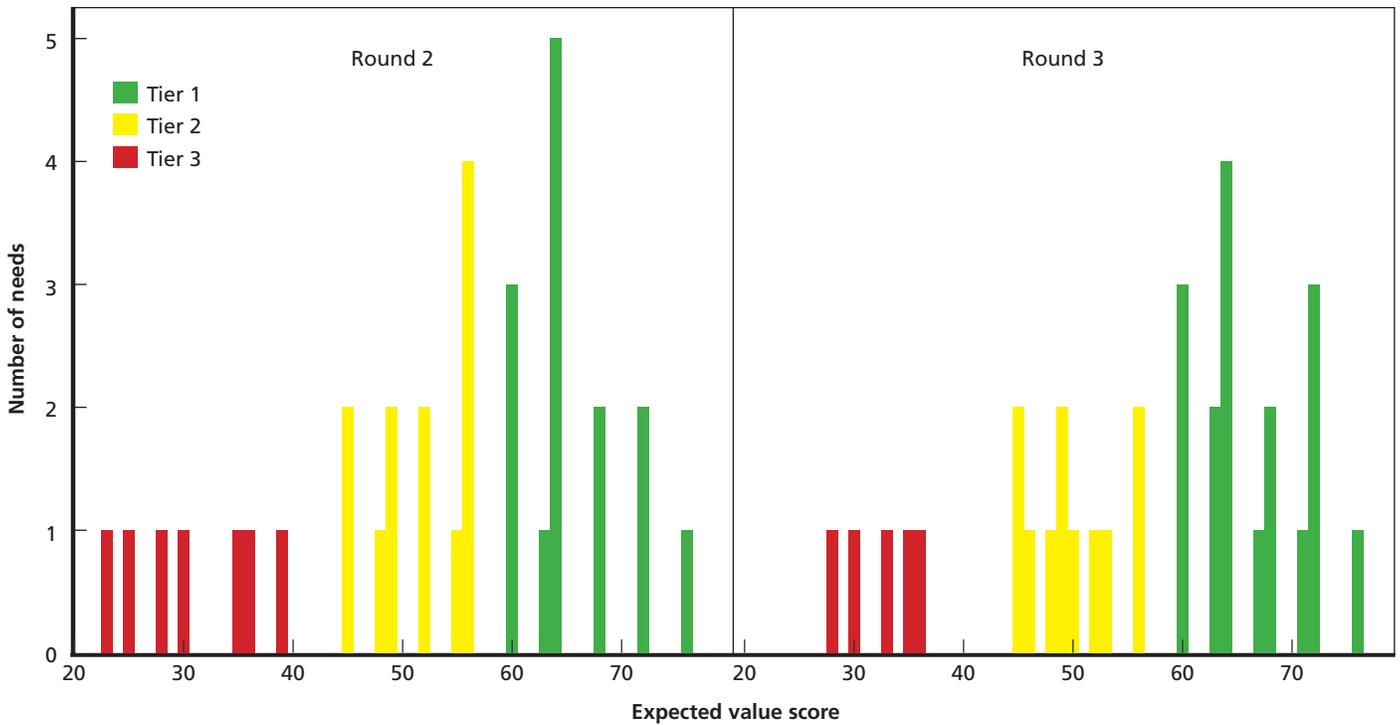


Table A.3. Complete List of Needs, by Tier

Problem or Opportunity	Need	Tier
Cybersecurity and AV communication		
Law enforcement often is unaware of whether a vehicle is capable of or authorized to run in automated mode.	<ul style="list-style-type: none"> <li>Conduct research to identify the costs and benefits of various options to identify capabilities and authorization to run in automated mode (e.g., annotation on the electronic registration records, indicator on license plate).</li> </ul>	1
There is a lack of understanding about cyber threats against privately owned or commercial vehicles.	<ul style="list-style-type: none"> <li>Conduct a threat analysis and risk assessment (TARA) of AVs and design tools to detect cyberattacks and facilitate investigation for law enforcement.</li> </ul>	
There is a lack of understanding about cyber threats to law enforcement activities (e.g., traffic stops, identification, remote kill-switch, data exfiltration).	<ul style="list-style-type: none"> <li>Conduct an analysis of attack models from the perspective of law enforcement agencies.</li> </ul>	
Law enforcement often is unaware of whether a vehicle is actually running in automated mode. <sup>a</sup>	<ul style="list-style-type: none"> <li>Conduct research to examine the costs and benefits of various options of communicating with AVs running in automated mode (e.g., vehicle-to-vehicle, communication between the light bar and AV).</li> </ul>	
Using only lights or sound to initiate a traffic stop can leave an AV vulnerable to hacking from unauthorized entities.	<ul style="list-style-type: none"> <li>Develop a system that allows authenticated agencies to communicate their intentions.</li> </ul>	
Law enforcement always needs to have the ability to communicate with something other than a computer (e.g., a responsible human that is the owner or operator).	<ul style="list-style-type: none"> <li>Develop the equivalent of “license and documentation” that allows law enforcement to check the authorization to operate an AV (and potentially talk with a responsible human).</li> </ul>	
Verbal and nonverbal (and voice-amplified) communication for traffic stops can be quite complex (e.g., asking vehicles to move into the next traffic lane, asking vehicles to move forward 100 yards, asking vehicles to move into a parking lot, indicating that a traffic stop is complete, or initiating special procedures for felony stops).	<ul style="list-style-type: none"> <li>Conduct research to identify the most-promising technological solutions that could be used in situations in which verbal communications are used (including assessments of potential adoption rates).</li> </ul>	
Stakeholder communication and collaboration		
There is a lack of real-world knowledge among law enforcement and other agencies about AV system capabilities and limitations.	<ul style="list-style-type: none"> <li>Conduct workshops and ride-alongs for law enforcement staff and other agency staff to raise knowledge levels.</li> </ul>	1
AV developers have the potential to report relevant information to dispatchers and first responders but lack clarity on what kinds of information would be most useful (e.g., location of incident, number of passengers, airbag deployment, vital signs).	<ul style="list-style-type: none"> <li>Conduct information-gathering exercises (e.g., workshops and surveys) to develop ideal approaches for conveying information to first responders.</li> </ul>	
At present, law enforcement does not have a thorough understanding of the kinds of information that is being collected by AVs and how long it is maintained so that they can request the most appropriate information (for the purposes of crash reconstruction).	<ul style="list-style-type: none"> <li>Conduct a survey of law enforcement and crash reconstruction experts to identify the type and quality of information that would be most useful (and potentially pass this along to standards committees).</li> </ul>	
It is important for law enforcement and other first responders to easily be able to stay current on procedures for accessing an AV (cutting power, towing, etc.).	<ul style="list-style-type: none"> <li>Develop model web portals that could inform original equipment manufacturers about the kinds of information that law enforcement would benefit from (e.g., law enforcement points of contact, instructional videos on how to cut power).</li> </ul>	

Table A.3—Continued

Problem or Opportunity	Need	Tier
There is a need for increased knowledge among AV system developers about how their product affects the community from a law enforcement perspective (e.g., traffic stop procedures, unique aspects of a jurisdiction).	<ul style="list-style-type: none"> <li>• Conduct workshops and ride-alongs for AV system developers to raise knowledge levels.</li> </ul>	
It might be difficult for law enforcement agencies to deal with AVs in areas of planned and unplanned closures (especially AVs that are operating without a capable operator as a backup). <sup>a</sup>	<ul style="list-style-type: none"> <li>• Identify best practices for cities and other entities that have information about upcoming closures to share information on events, closures, etc. (This is useful only for planned closures.)</li> </ul>	
<b>Standard procedures, guidelines, and training</b>		
Law enforcement often is unaware of whether a vehicle is actually running in automated mode. <sup>a</sup>	<ul style="list-style-type: none"> <li>• Develop model training and guides for law enforcement for identifying and interacting with AVs running in automated mode.</li> </ul>	1
Law enforcement might have to respond to scenarios in which vehicles have been hacked and are not operable (e.g., from ransomware).	<ul style="list-style-type: none"> <li>• Develop guides and tools for potential law enforcement responses to AV hacking.</li> </ul>	
Law enforcement might have to adapt tactics and procedures when AV technologies are employed incorrectly, improperly, or illegally.	<ul style="list-style-type: none"> <li>• Develop a guide containing likely scenarios in which AVs are used illegally and potential solutions.</li> </ul>	
There is not a consistent set of “traffic stop” maneuvers that AVs will be expected to perform.	<ul style="list-style-type: none"> <li>• Develop a general description of the kinds of behaviors that law enforcement will expect AVs to be able to perform that is representative across the United States.</li> </ul>	
<b>Cybersecurity and AV communication</b>		
It might be difficult for law enforcement agencies to deal with AVs in areas of planned and unplanned closures (especially AVs that are operating without a capable operator as a backup). <sup>a</sup>	<ul style="list-style-type: none"> <li>• Develop a standard that would allow regional communications to vehicles for exchange of information about closures.</li> </ul>	2
In a situation in which law enforcement needs to communicate with an AV and there are multiple AVs present, it might not be clear to AVs or law enforcement which vehicle is being communicated with.	<ul style="list-style-type: none"> <li>• Conduct research to identify the most-promising technological solutions that could be used in such situations.</li> </ul>	
<b>Stakeholder communication and collaboration</b>		
AVs could collect data as “witnesses” to events in which they were not involved. <sup>a</sup>	<ul style="list-style-type: none"> <li>• Conduct a survey of law enforcement and crash reconstruction experts to identify the types of information that would be most useful (and potentially pass this information to standards committees).</li> <li>• Identify and support law enforcement expert participation in standards- and policy-development committees that potentially are examining these issues.</li> </ul>	2
It is important for law enforcement to be able to get in touch with AV original equipment manufacturers quickly in case of emergency or if they need to serve legal process.	<ul style="list-style-type: none"> <li>• Develop model web portals that could inform original equipment manufacturers about the kinds of requests that law enforcement would like to be able to submit (e.g., subpoenas, data requests).</li> </ul>	
Law enforcement can be unaware of the companies and types of AVs that are operating within their jurisdictions.	<ul style="list-style-type: none"> <li>• Develop a regionally centralized data store where this kind of information can be shared.</li> </ul>	
When agencies retrieve AV data, it is often difficult (or expensive) to be able to interpret those data.	<ul style="list-style-type: none"> <li>• Develop a standard that allows an interchange of data among vehicles, law enforcement, prosecutors, etc.</li> </ul>	

Table A.3—Continued

Problem or Opportunity	Need	Tier
It might be difficult for law enforcement agencies to deal with AVs in areas of planned and unplanned closures (especially AVs that are operating without a capable operator as a backup). <sup>a</sup>	<ul style="list-style-type: none"> <li>• Develop regionally centralized data store where this kind of information can be shared.</li> </ul>	
When law enforcement agencies need to rely on manufacturers or operating companies to obtain the data needed to investigate a crash, there are potential chain-of-custody issues.	<ul style="list-style-type: none"> <li>• Conduct research to identify the breadth and depth (scope) of the problem.</li> </ul>	
Standard procedures, guidelines, and training		
There are a variety of types of data that agencies need to extract or request to assess the behavior of a vehicle (e.g., throttle, braking, and steering commands, objects detected, camera views).	<ul style="list-style-type: none"> <li>• Develop a set of reasonable practices, questions, and/or model subpoenas that would help law enforcement agencies.</li> </ul>	2
There are not definitions of <i>evidence collection</i> that are useful to the industry.	<ul style="list-style-type: none"> <li>• Develop a general description that is representative of the kinds of situations encountered across the United States of the kinds of information that law enforcement will expect AVs to provide.</li> </ul>	
Cybersecurity and AV communication		
There is a lack of knowledge about user (passenger or operator) reactions when facing cyberattacks (i.e., How should users react if they experience something strange?).	<ul style="list-style-type: none"> <li>• Conduct a study of human factors and cybersecurity to produce guidelines for educating citizens on what to do when experiencing a cyber-physical crime.</li> </ul>	3
Law enforcement might have to respond to scenarios in which vehicles have been hacked and are being directed to do something undesirable (e.g., driving on the sidewalk).	<ul style="list-style-type: none"> <li>• Develop guides and tools for potential law enforcement responses, which might include controls or overrides that would be available to law enforcement.</li> </ul>	
Stakeholder communication and collaboration		
It is difficult for AVs to determine the differences between accepted common practices and the letter of the law so that traffic flow and safety are not adversely affected (e.g., short-term double parking, crossing a double yellow line to avoid an obstruction).	<ul style="list-style-type: none"> <li>• Conduct information-gathering exercises (e.g., workshops and ride-alongs) to examine common patterns and practices among human drivers that are officially illegal but where officers might exercise discretion (and assess the implications of such practices).</li> </ul>	3
Standard procedures, guidelines, and training		
When law enforcement agencies need to rely on manufacturers or operating companies to obtain the data needed to investigate a crash, there are potential Fifth Amendment (i.e., right not to self-incriminate) issues.	<ul style="list-style-type: none"> <li>• Conduct research to identify the breadth and depth (scope) of the problem.</li> </ul>	3
There are situations in which there are large numbers of abandoned vehicles that might need to be moved by law enforcement (e.g., extreme weather events or other disasters).	<ul style="list-style-type: none"> <li>• Develop a system to facilitate the removal of disabled AVs (commercial, rideshare, etc.).</li> </ul>	

<sup>a</sup> This problem or opportunity is associated with needs that fell into different tiers.

## Note

<sup>1</sup> We acknowledge that techniques that fraudulently communicate LE imperatives also can be used to trick human drivers and few—if any—people are overly concerned about this possibility. We note, however, that in these cases, human drivers have the power to refuse to stop if they recognize that commands are not actually coming from LE, whereas occupants of an AV might not have that option.

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## Acknowledgments

The authors would like to acknowledge the participation and assistance of the members of the workshop, who are listed in the body of this report. This effort would not have been possible without their willingness to participate. The authors also would like to acknowledge the contributions of Steve Schuetz of the National Institute of Justice. We are also thankful for the valuable contributions of the anonymous reviewers from the U.S. Department of Justice and the peer reviewers of the report, Laura Fraade-Blanar of the RAND Corporation and Thomas J. Cowper of the Lifeboat Foundation.

## The RAND Justice Policy Program

RAND Social and Economic Well-Being is a division of the RAND Corporation that seeks to actively improve the health and social and economic well-being of populations and communities throughout the world. This research was conducted in the Justice Policy Program within RAND Social and Economic Well-Being. The program focuses on such topics as access to justice, policing, corrections, drug policy, and court system reform, as well as other policy concerns pertaining to public safety and criminal and civil justice. For more information, email [justicepolicy@rand.org](mailto:justicepolicy@rand.org).

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## About This Report

On behalf of the U.S. Department of Justice, National Institute of Justice (NIJ), the RAND Corporation, in partnership with the Police Executive Research Forum (PERF), RTI International, and the University of Denver, is carrying out a research effort to assess and prioritize technology and related needs across the criminal justice community. This research effort, called the Priority Criminal Justice Needs Initiative, is a component of the Criminal Justice Requirements & Resources Consortium (RRC), and is intended to support innovation within the criminal justice enterprise. For more information about the RRC and the Priority Criminal Justice Needs Initiative, please see [www.rand.org/well-being/justice-policy/projects/priority-criminal-justice-needs](http://www.rand.org/well-being/justice-policy/projects/priority-criminal-justice-needs).

This report is one product of that effort. In July 2019, PERF and RAND researchers conducted an expert workshop to assess near-term law enforcement needs related to autonomous vehicles (AVs). This report presents the proceedings of that workshop, topics considered, needs that the panel participants developed, and overarching themes that emerged from the panel discussions. This report and the results it presents should be of interest to law enforcement agencies in jurisdictions with AV programs, organizations that manufacture or operate AVs, regions and municipalities that expect a growing presence of AVs in the short term, and coordinating bodies addressing the needs of these groups.

Other RAND research reports from the Priority Criminal Justice Needs Initiative that might be of interest are

- John S. Hollywood, Sean E. Goodison, Dulani Woods, Michael J. D. Vermeer, and Brian A. Jackson, *Fostering Innovation to Respond to Top Challenges in Law Enforcement: Proceedings of the National Institute of Justice's 2018 Chiefs' Panel on Priority Law Enforcement Issues and Needs*, Santa Monica, Calif.: RAND Corporation, RR-2930-NIJ, 2019
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This publication was made possible by Award Number 2018-75-CX-K006, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, conclusions, and recommendations expressed in this publication are those of the author(s) and do not necessarily reflect those of the Department of Justice, the RAND Corporation, or the organizations represented by any of the workshop participants.

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