



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

AUTONOMOUS POLICE VEHICLES: THE IMPACT ON LAW ENFORCEMENT

by

Andrew Gregg

March 2019

Co-Advisors:

Robert L. Simeral
Lauren Wollman (contractor)

Approved for public release. Distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE March 2019	3. REPORT TYPE AND DATES COVERED Master's thesis		
4. TITLE AND SUBTITLE AUTONOMOUS POLICE VEHICLES: THE IMPACT ON LAW ENFORCEMENT			5. FUNDING NUMBERS	
6. AUTHOR(S) Andrew Gregg				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) The rapid deployment of autonomous vehicle (AV) technology will undoubtedly have a significant impact on public safety services, including law enforcement agencies. Law enforcement can embrace AV technology, with the advent of autonomous police vehicles (APVs). The APV is designed with standard AV technology but is also packaged with complementary technologies, including an integrated unmanned aircraft system (UAS), facial recognition, thermal imaging, automated license plate readers, and gunshot detection systems. The anticipated benefits and unintended consequences of emerging technologies, such as the APV, are not always assessed by law enforcement. Thus, the goal of this thesis was to determine the likely impacts on law enforcement of the deployment of the APV. This thesis examined emerging AV technologies and complementary technologies, and analyzed plausible future scenarios to lend insight to public safety executives on the changing roles, mission, and tasks law enforcement officers may encounter. This thesis determined that the APV benefits to law enforcement, such as improving officer efficiency and officer safety likely outweigh the trepidations. This thesis recommends that law enforcement agencies should find a void to fill when the APV becomes realized. This void may only present itself once the APV is in service and fully functional; thus, law enforcement agencies should be mindful of this possible void in order to pivot for sustained future success.				
14. SUBJECT TERMS autonomous vehicles, autonomous police vehicles, connected vehicle technology, Internet of things, car-to-car technology, self-driving vehicle, self-driving police vehicle, driverless vehicle, driverless police vehicle, automated vehicle, automated police vehicle, self-driving car, self-driving police car, driverless car, driverless police car, automated car, automated police car, law enforcement, law-enforcement policy, public safety			15. NUMBER OF PAGES 131	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

**AUTONOMOUS POLICE VEHICLES:
THE IMPACT ON LAW ENFORCEMENT**

Andrew Gregg
Lieutenant, California Highway Patrol
BS, Iowa State University, 1997

Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
March 2019**

Approved by: Robert L. Simeral
Co-Advisor

Lauren Wollman
Co-Advisor

Erik J. Dahl
Associate Chair for Instruction
Department of National Security Affairs

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The rapid deployment of autonomous vehicle (AV) technology will undoubtedly have a significant impact on public safety services, including law enforcement agencies. Law enforcement can embrace AV technology, with the advent of autonomous police vehicles (APVs). The APV is designed with standard AV technology but is also packaged with complementary technologies, including an integrated unmanned aircraft system (UAS), facial recognition, thermal imaging, automated license plate readers, and gunshot detection systems. The anticipated benefits and unintended consequences of emerging technologies, such as the APV, are not always assessed by law enforcement. Thus, the goal of this thesis was to determine the likely impacts on law enforcement of the deployment of the APV. This thesis examined emerging AV technologies and complementary technologies, and analyzed plausible future scenarios to lend insight to public safety executives on the changing roles, mission, and tasks law enforcement officers may encounter. This thesis determined that the APV benefits to law enforcement, such as improving officer efficiency and officer safety likely outweigh the trepidations. This thesis recommends that law enforcement agencies should find a void to fill when the APV becomes realized. This void may only present itself once the APV is in service and fully functional; thus, law enforcement agencies should be mindful of this possible void in order to pivot for sustained future success.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	PROBLEM STATEMENT	2
B.	RESEARCH QUESTION	4
C.	LITERATURE REVIEW	4
1.	Autonomous Vehicle Technology	4
2.	Complementary Technologies.....	9
D.	RESEARCH DESIGN	16
1.	Data Sources	16
2.	Analytical Steps	16
3.	Output	17
E.	CHAPTER SUMMARY.....	17
II.	AUTONOMOUS POLICE VEHICLE OVERVIEW.....	19
A.	AUTONOMOUS VEHICLE BACKGROUND	19
1.	Levels of Autonomous Vehicle Technology	20
2.	Autonomous Vehicle Technologies	21
3.	Potential Benefits	22
4.	AV State of Readiness.....	24
B.	AUTONOMOUS POLICE VEHICLE BACKGROUND.....	27
C.	CHAPTER SUMMARY.....	30
III.	AUTONOMOUS POLICE VEHICLE PLATFORM— COMPLEMENTARY TECHNOLOGIES.....	33
A.	UNMANNED AIRCRAFT SYSTEM	33
B.	THERMAL IMAGING SENSORS.....	35
C.	AUTOMATED LICENSE PLATE READERS	37
D.	AIR SAMPLING SENSORS	40
E.	FACIAL RECOGNITION.....	42
F.	GUNSHOT DETECTION SYSTEMS.....	44
G.	THROUGH-THE-WALL SENSORS	46
H.	CHAPTER SUMMARY.....	47
IV.	AUTONOMOUS POLICE VEHICLE CONSIDERATIONS.....	49
A.	APV BENEFITS.....	49
1.	Efficiency	50
2.	Officer Safety.....	52

3.	Improving Fugitive Searches and Search and Rescue Operations	56
4.	Community Policing	57
5.	Support and Coordination with Fire and EMS and Other Government Agencies	59
B.	APV CONCERNS	60
1.	Weaponization	60
2.	Kill Switch Technologies	63
3.	Privacy Issues	65
4.	Legal Considerations	66
C.	CHAPTER SUMMARY	69
V.	ANALYSIS—IMAGINING THE UNEXPECTED	71
A.	SCENARIOS	71
1.	First Scenario: The Lone Patrol Officer	71
2.	First Scenario Summary	74
3.	Second Scenario: The Skilled Community Officer	74
4.	Second Scenario Summary	76
5.	Third Scenario: The Technical Commercial Officer	77
6.	Third Scenario Summary	79
B.	SCENARIO FINDINGS AND UNINTENDED CONSEQUENCES	80
1.	Technological Unemployment	80
2.	Lost Perishable Skills	83
3.	Shifting Hiring Practices	86
C.	CHAPTER SUMMARY	88
VI.	RECOMMENDATIONS AND CONCLUSION	89
A.	THE INDISPENSABLE PIVOT	89
B.	CONCLUSION	93
	LIST OF REFERENCES	95
	INITIAL DISTRIBUTION LIST	111

LIST OF FIGURES

Figure 1.	Levels of Vehicle Autonomy	21
Figure 2.	AV Technologies	22
Figure 3.	The Connected APV Network	29

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

ADS	automated driving systems
ALPR	automated license plate reader
APV	autonomous police vehicle
AV	autonomous vehicle
AVRI	autonomous vehicle readiness index
CBP	Customs and Border Protection
CoE	Center of Excellence
COPS	Community Oriented Policing Services
DEA	Drug Enforcement Administration
DHS	Department of Homeland Security
DOJ	Department of Justice
DUI	driving under the influence
DTO	drug trafficking organizations
EMS	emergency medical service
FBI	Federal Bureau of Investigation
FLIR	forward looking infrared
IFSTA	International Fire Service Training Association
ILS	intracavity laser spectroscopy
IoT	Internet of things
ISIS	Islamic State of Iraq and Syria
IT	information technology
IR	infrared
LIDAR	light detection and ranging
MDT	mobile digital terminal
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
NIJ	National Institute of Justice
NVC	night vision camera
PCSO	Pinellas County Sheriff's Office
PIT	precision immobilization technique

RDW	Road Transport Agency
SSBT	sensor, surveillance, and biometric technologies
sUAS	small unmanned aircraft systems
SUV	sport utility vehicle
TTWS	through-the-wall sensor
UAS	unmanned aircraft system
USPS	United States Postal Service
VBIED	vehicle borne improvised explosive device

EXECUTIVE SUMMARY

Technology, like art, is a soaring exercise of the human imagination.

—Daniel Bell,
American sociologist

In the past several years, the autonomous vehicle has evolved from a possibility to an inevitability. AV technology will undoubtedly impact public safety services, including law enforcement agencies. Law enforcement can embrace AV technology with the advent of autonomous police vehicles (APVs). The APV is designed with standard AV technology but is also packaged with complementary technologies including an integrated unmanned aircraft system (UAS), facial recognition, thermal imaging, automated license plate readers, air sampling devices and gunshot detection systems. The APV can be used by law enforcement agencies to conduct surveillance or “patrol autonomously based upon current threats, criminality patterns, or community requests.”¹

Law enforcement agencies have an abundance of technological opportunities, such as “analytics, artificial intelligence, and the Internet of Things.”² Law enforcement agencies must identify the “technologies and practices with the most potential for improving public safety.”³ Although the APV is in its infancy in the United States, it is a technology with the ability to improve public safety. Emerging technologies, such as the APV, have typically had a favorable impact, but the anticipated benefits and unintended consequences on police officers are not always assessed beforehand.⁴ These effects are

¹ Thomas J. Cowper and Bernard H. Levin, “Autonomous Vehicles: How Will They Challenge Law Enforcement?” FBI Law Enforcement Bulletin, February 13, 2018, <https://leb.fbi.gov/articles/featured-articles/autonomous-vehicles-how-will-they-challenge-law-enforcement>.

² Hollywood et al., *Emerging Technology Trends and Their Impact on Criminal Justice* (Santa Monica, CA: RAND, 2018), https://www.rand.org/pubs/research_briefs/RB9996.html, 1.

³ Hollywood et al., 1.

⁴ Hollywood et al., 2.

often missed by law enforcement agencies due to a “lack of implementation plans and procedures.”⁵

The goal of this thesis is to assist law enforcement agencies preparing for the future implementation of the APV by lending insight to public safety executives on the changing roles, mission, and tasks law enforcement officers may encounter. This goal is accomplished by examining emerging AV technologies, complementary technologies and analyzing plausible future scenarios. This thesis gives the reader an understanding of the potential intended and unintended consequences of APV implementation and its impact on the law enforcement officer.

The APV would ostensibly benefit law enforcement in many ways, such as by improving officer efficiency, officer safety, fugitive searches, rescue operations, community policing, and public safety communications. However, several potential APV concerns have also been raised. Some of these trepidations include privacy and legal drawbacks, as well as the potential to weaponize the APV. The positive effects of the APV appear to outweigh the shortcomings, and thus, it is only a matter of time before the APV is implemented by law enforcement agencies. However, prior to this implementation, law enforcement agencies must consider what the unintended consequences of the APV may be. These unintended consequences may be a reduced law enforcement workforce that has enhanced information technology (IT) skills, but a reduced practical skillset. While not a specific issue for some, law enforcement agencies should be aware of these factors to mitigate any potential concerns.

Not anticipating and understanding these factors can be detrimental for law enforcement agencies implementing the APV. Research has shown that other public organizations, such as fire departments, have adapted to new technologies in their field by identifying a void that needs to be filled. The APV will ultimately have a significant impact on law enforcement agencies with endless opportunities while at the same time reducing the risk to its officers, therefore, this thesis recommends that law enforcement agencies should find a void to fill when the APV becomes realized. This void may only

⁵ Hollywood et al., 1.

present itself once the APV is in service and fully functional; thus, law enforcement agencies should be mindful of this possible void in order to pivot for sustained future success.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I am extremely appreciative of the California Highway Patrol for allowing me the opportunity to pursue a higher education and for supporting me in the process. This journey could not have been accomplished without the unwavering support of several people. Thank you to Assistant Chief Jesus Holguin and Captain Tai Vong for your endorsement, encouragement, and support during my participation in the Center for Homeland Defense and Security program and for allowing me to pursue my master's degree. I also want to thank my colleagues, especially Lieutenant Geletko (retired), and Lieutenant Workman, who covered for me while I was away at the Naval Postgraduate School.

In addition, I would like to express my special thanks and gratitude to my advisors, Dr. Lauren Wollman and Captain Robert Simeral, for your encouragement and guidance throughout the thesis process. I would not have crossed the finish line without your much-needed assistance.

Finally, I would like to recognize and thank my family for their steadfast love, patience, and encouragement during this challenging voyage. I will forever be grateful for the sacrifices you made over the past 18 months by affording me the time to complete the program successfully. I truly could not have done it without your help, thank you!

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

Autonomous vehicle (AV) technology is rapidly evolving, with one estimate suggesting 100,000 such vehicles will be navigating American streets and roadways by the year 2021.¹ In the past several years, the AV has evolved from a possibility to an inevitable reality. Waymo, the company developed from Google's self-driving car project, has AVs that have been driven over seven million miles in six states and 25 cities.² In December 2018, Waymo started its commercial self-driving vehicle service in Phoenix, AZ that allowed its vehicles to be hailed by a 24-hour a day app.³ Waymo will be expanding its commercial self-driving service in the next few years, although its initial monopoly on the AV has already disappeared.⁴ Tesla has been testing AVs that have accumulated over 1.2 billion miles in Autopilot since October 2015.⁵ Audi, BMW, GM, Nissan, Volvo, Bosch, Daimler, and Continental are just some of the other auto manufacturers investing in AV technology.⁶ Startups, such as May Mobility and Drive.ai, as well as the ride-sharing companies Uber and Lyft, are also entering the AV market.⁷ AV technology is forging ahead and by all accounts is here to stay.

It is widely assumed that AVs will be safer and more efficient than human drivers because they will be equipped to monitor driving conditions continually on the roadways,

¹ Paul A. Eisenstein, "Self-Driving Cars Take to the Road, but Not Everyone Is Ready to Ride," CNBC, October 14, 2018, <https://www.cnbc.com/2018/10/14/self-driving-cars-take-to-the-road-but-not-everyone-is-ready-to-ride.html>.

² "On the Road," Waymo, accessed October 17, 2017, <https://waymo.com/ontheroad/>.

³ Pete Bigelow, "Google's Robotaxis Are up and Running as of Today," AdAge, December 5, 2018, <https://adage.com/article/cmo-strategy/waymo-s-commercial-driving-service-launches-today/315881/>.

⁴ Alex Davies, "The Wired Guide to Self-Driving Cars," Wired, December 13, 2018, <https://www.wired.com/story/guide-self-driving-cars/>.

⁵ Lex Fridman, "Tesla Autopilot Miles," *MIT Human-Centered AI* (blog), last updated January 3, 2019, <https://hcai.mit.edu/tesla-autopilot-miles/>.

⁶ Xavier Mosquet et al., "Revolution in the Driver's Seat: The Road to Autonomous Vehicles," Boston Consulting Group, April 21, 2015, <https://www.bcg.com/publications/2015/automotive-consumer-insight-revolution-drivers-seat-road-autonomous-vehicles.aspx>.

⁷ Davies, "The Wired Guide to Self-Driving Cars."

which will cause fewer traffic collisions and traffic violations.⁸ AV technology will also undoubtedly impact public safety services, including law enforcement agencies. With both driverless and human-operated vehicles on the roadways, law enforcement agencies will have to adapt to and plan for this emerging technology with revised traffic enforcement and patrol procedures.

A. PROBLEM STATEMENT

In addition to responding to the presence of automated vehicles on the road, law enforcement can also embrace the technology themselves, with autonomous police vehicles (APVs). APVs can be used as a “mobile observation” platform outfitted with “cameras, license plate readers, radar, and gunshot detection systems.”⁹ Law enforcement agencies can also use them to conduct surveillance or “patrol autonomously based upon current threats, criminality patterns, or community requests.”¹⁰ Small-scale APVs were first introduced in the summer of 2017, when the Dubai Police Department unveiled autonomous self-driving miniature police vehicles.¹¹ These autonomous patrol vehicles come packed with technology that “patrol[s] the city to boost security and hunt[s] for unusual activity.”¹² They also operate while being unoccupied and use biometric software to scan for known criminals and persons of interest.¹³ These vehicles are being used in place of human police officers in certain regions within the city to augment the police

⁸ Cadie Thompson, “Why Driverless Cars Will Be Safer than Human Drivers,” *Business Insider*, November 16, 2016, <http://www.businessinsider.com/why-driverless-cars-will-be-safer-than-human-drivers-2016-11>.

⁹ Thomas J. Cowper and Bernard H. Levin, “Autonomous Vehicles: How Will They Challenge Law Enforcement?” *FBI Law Enforcement Bulletin*, February 13, 2018, <https://leb.fbi.gov/articles/featured-articles/autonomous-vehicles-how-will-they-challenge-law-enforcement>.

¹⁰ Cowper and Levin.

¹¹ Jojo Puthuparampil, “Dubai, Say Hello to These New Self-Driving Police Vehicles,” *Inc. Arabia* (blog), June 29, 2017, <http://www.incarabia.com/technology/dubai-say-hello-to-these-new-self-driving-police-vehicles/>.

¹² Puthuparampil.

¹³ Tom Page, “Self-Driving Police Patrol to Hit Dubai,” *CNN*, June 30, 2017, <http://www.cnn.com/style/article/dubai-police-self-driving-vehicle-o-r3/index.html>.

force.¹⁴ The introduction of the small-scale APV is the first step in augmenting Dubai's police department, which wants 25 percent of the department to be autonomous, and eventually, to "police without policemen," by utilizing police vehicles, robots, and advanced technologies to enforce the law.¹⁵ The Dubai Police Department's progression to eliminate police officers through advanced technologies may be indicative of an emerging trend.

In January 2018, the Ford Motor Company was issued a patent for an APV that can operate "in lieu of or in addition to human police officers."¹⁶ The APV will be able to identify violations of traffic laws and automatically maneuver behind the offender to initiate a traffic stop.¹⁷ While the APV is idle, "it may learn to park where violations of traffic can be viewed."¹⁸ Ford's patent has not yet come to fruition, yet it indicates a potential law enforcement technological shift towards AVs in the United States. Police officer functions, tasks, and future missions may ultimately change with the implementation of the APV.

Law enforcement agencies have an abundance of technological opportunities, such as "analytics, artificial intelligence, and the Internet of Things."¹⁹ Law enforcement agencies must recognize the "technologies and practices with the most potential for improving public safety."²⁰ Although the APV is in the infancy stage of development and not yet realized in the United States, it is a technology with the ability to improve public safety. Emerging technologies, such as the APV, have typically had a favorable impact

¹⁴ James Vincent, "Police in Dubai Have Recruited a Self-Driving Robo-Car that Can 'Scan for Undesirables,'" *The Verge*, June 29, 2017, <https://www.theverge.com/2017/6/29/15893802/dubai-police-robot-drone-car>.

¹⁵ "Dubai Aims to Remove Police Officers from Streets," *Gulf Business* (blog), March 13, 2018, <https://gulfbusiness.com/dubai-aims-remove-police-officers-from-streets/>.

¹⁶ Mohamed Ahmed et al., *Autonomous police vehicle*, U.S. Patent Application, filed July 12, 2016, <http://www.freepatentsonline.com/20180018869.pdf>.

¹⁷ Benjamin Joe, "Ford Developing Autonomous Systems for Police Cars, Other Emergency Vehicles," *IPWatchdog*, April 7, 2018, <http://www.ipwatchdog.com/2018/04/07/ford-developing-autonomous-systems-police-cars-emergency-vehicles/id=95218/>.

¹⁸ Joe.

¹⁹ Hollywood et al., *Emerging Technology Trends and Their Impact on Criminal Justice* (Santa Monica, CA: RAND, 2018), https://www.rand.org/pubs/research_briefs/RB9996.html, 1.

²⁰ Hollywood et al., 1.

when implemented; however, the unanticipated benefits and the unintended consequences on police officers are not always assessed.²¹ These results are often missed by law enforcement agencies due to a “lack of implementation plans and procedures.”²² This thesis course corrects and assists law enforcement agencies preparing for the future implementation of the APV.

B. RESEARCH QUESTION

What are the likely impacts on law enforcement from the deployment of APVs?

C. LITERATURE REVIEW

This literature review is an evaluation of the most relevant literature currently available on the use of an APV platform. Due to the limited operation worldwide of such a platform, much of the research revolves around complementary technologies that have been implemented in the law enforcement community, such as the unmanned aircraft system (UAS) and wireless sensor networks. These technologies have been successfully developed in many law enforcement agencies, which ultimately impacts the mission of the law enforcement officer. The literature comes from several sources, such as professional journals, government reports, experts from within the field of sensor networks, official U.S. federal agency websites, and global think tanks, such as the RAND Corporation.

1. Autonomous Vehicle Technology

The National Highway Traffic Safety Administration (NHTSA) has written extensively on the use of automated driving systems (ADS) in the United States. Their research is invaluable because it sets the federal guidelines for AVs. The NHTSA’s current report, released in 2018, expands the scope of their previous reports to include all surface on-road transportation systems.²³ Additionally, their report provides an overview

²¹ Hollywood et al., 2.

²² Hollywood et al., 1.

²³ “Automated Driving Systems,” National Highway Traffic Safety Administration, August 2018, <https://www.nhtsa.gov/vehicle-manufacturers/automated-driving-systems>.

of vehicle safety for automated vehicles and discusses the evolution (five eras) of automated safety technologies.²⁴ Most importantly, NHTSA provides a taxonomy of the levels of driving automation, which ranges from “Level 0 (no driving automation)” to “Level 5 (full driving automation).”²⁵ These level definitions are used to create a consistent framework to describe the full range of driving automation equipped on motor vehicles. These levels set the standard for the future development of APVs, as all AVs, regardless of the platform, must follow these guidelines. Essentially, NHTSA’s reports and guidelines must be included in all future research and expansions of AVs.

Bel Geddes made the first promise of AVs in 1939 during a Futurama exhibition at the New York’s World Fair.²⁶ Geddes speculated, as does the bulk of the early AV and robotics literature, on what “society would look like in [the] future.”²⁷ However, the majority of the early research focused on how automation would drastically change the processes in an industrial factory. Royakkers and Rinie van Est, writing in 2015, Lambèrdeviate from this research and focused “on how the use of robotics outside the factory will change our lives over the coming decades.”²⁸ They argue that robotics no longer applies to just factory applications, as robotics are being used in a more complicated and complex ways, as automation covers everything from “love to war.”²⁹ Royakkers and Est’s exploration of robotics is relevant, as it identifies that the law enforcement field is an essential domain in expanding the technology.³⁰ They estimate AVs will be fully functioning in the next 10 years. Additionally, they discern that the development of the “police robot” is making considerable headway in the United States, specifically in “carrying out surveillance and disarming explosives.”³¹ While their

²⁴ National Highway Traffic Safety Administration.

²⁵ National Highway Traffic Safety Administration.

²⁶ Lambèr Royakkers and Rinie van Est, “A Literature Review on New Robotics: Automation from Love to War,” *International Journal of Social Robotics* 7, no. 5 (November 1, 2015): 549–70, <https://doi.org/10.1007/s12369-015-0295-x>.

²⁷ Royakkers and van Est., 557.

²⁸ Royakkers and van Est., 549.

²⁹ Royakkers and van Est., 570.

³⁰ Royakkers and van Est., 550.

³¹ Royakkers and van Est., 558.

research does not discuss APVs, it makes the argument that both the robot car and police robot are essential technologies that law enforcement must be prepared for in the near future. John S. Hollywood, Dulani Woods, and Richard S. Silberglitt further the argument that law enforcement agencies must tap into existing technologies to strengthen criminal justice.³² Their report, written in 2015, highlights the results submitted from a panel of law enforcement experts during a criminal justice workshop. They specifically discuss how privacy, civil rights, and security risks of emerging technologies must be addressed by law enforcement agencies.³³ While not germane to APVs, Hollywood, Woods, and Silberglitt's research discusses the concept of operations of new technologies, which is applicable to APV implementation.

James M. Anderson et al. were some of the first to discuss both the opportunities and barriers of AVs.³⁴ Anderson et al. are researchers for the RAND Corporation, which has provided a significant contribution to research in the advanced technologies field. Anderson et al. discuss both the benefits and drawbacks of AV technology, who observe that the technology "offers the possibility of fundamentally changing transportation."³⁵ However, they recognize that AV technology has liability implications.³⁶ They determine that while more research will be needed, the liability may shift from the driver to the manufacturer in future traffic collisions, depending on what regulatory schemes arise with this emerging technology.³⁷ Their research on AVs is essential to both state and federal policymakers on the issues that the technology raises. This research will also extend to law enforcement decision makers contemplating APV technology.

Daniel J. Fagnant and Kara Kockelman have expanded on Anderson et al.'s research. They argue that the benefits of AVs significantly outweigh the costs. Fagnant

³² John S. Hollywood et al., *Using Future Internet Technologies to Strengthen Criminal Justice* (Santa Monica, CA: RAND, 2015), 1.

³³ Hollywood et al., 1.

³⁴ James M. Anderson et al., *Autonomous Vehicle Technology: A Guide for Policymakers* (Santa Monica, CA: RAND, 2014), 9–40.

³⁵ Anderson et al., xiii.

³⁶ Anderson et al., 111–132.

³⁷ Anderson et al., 115.

and Kockelman conclude that the opportunities presented by AV are many, such as “averting deadly crashes, providing critical mobility to the elderly and disabled, increasing road capacity, saving fuel, and lower emissions.”³⁸ Another benefit realized by the team is that the “passenger compartment may be transformed” to allow passengers to focus on other activities rather than driving, which increases the productivity of the workforce to complete tasks during their previously unproductive commute times.³⁹ Fagnant and Kockelman acknowledge potential barriers, such as privacy, legal, and security concerns. Specific to security concerns, Fagnant and Kockelman identify computer hackers, terrorist organizations, and hostile nations as potential threats to AVs.⁴⁰ However, they determine that having a robust defense against such attacks will limit the advent of such an occurrence.⁴¹ Even though Fagnant and Kockelman’s article does not provide a law enforcement or public safety perspective, their research is critical to the further development of the APV because it provides a framework for how AVs should be studied going forward.

Aristotle Wolfe’s AV thesis discusses the unintended consequences of the technology in great detail.⁴² Written in 2017, his thesis studies how AVs will impact traffic enforcement by law enforcement agencies. Wolfe predicts that an unintended consequence will be “a diminished capacity for police to detect and deter crime in the same ways they do today.”⁴³ Wolfe also determines that additional unintended consequences may be “increased contraband traffic” and “weaponization.”⁴⁴ This research is noteworthy, as significant value is added to the argument of APVs, and how law enforcement agencies must adapt to the emerging technology in the next few years.

³⁸ Daniel J. Fagnant and Kara Kockelman, “Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations,” *Transportation Research Part A-Policy and Practice* 77 (July 2015): 167–81, <https://doi.org/10.1016/j.tra.2015.04.003>.

³⁹ Fagnant and Kockelman, 168.

⁴⁰ Fagnant and Kockelman, 177.

⁴¹ Fagnant and Kockelman, 177.

⁴² Aristotle Wolfe, “Unstoppable? The Gap between Public Safety and Traffic Safety in the Age of Driverless Cars” (master’s thesis, Naval Postgraduate School, 2017), 70.

⁴³ Wolfe, xvii.

⁴⁴ Wolfe, 71.

The majority of the literature does not specifically address APVs, which is why Robert Finkelstein and Rob Davis' white paper, written in 2017, may be the most meaningful research conducted on the technology. The researchers teamed up with Robotic Technology Inc., and the non-profit Police Foundation, respectively, to determine whether law enforcement opportunities were available within AV technology. They conclude that law enforcement agencies "must take advantage of the benefits of the technology with their fleets of autonomous police cruisers and other vehicles."⁴⁵ Finkelstein and Davis predict that within the next several years, law enforcement agencies will start purchasing AVs as an inexpensive tool to replace or supplement officers on "foot, horses, or bicycles, or in patrol cars."⁴⁶ Furthermore, Finkelstein and Davis surmise that law enforcement strategies, procedures, and policies will change to optimize the new technology.⁴⁷ The researchers also acknowledge the AV has characteristics advantageous to law enforcement agencies. Specifically, they conclude the APV can be operated staffed or unstaffed.⁴⁸ Operating staffed or unstaffed allows an autonomous law enforcement fleet to be designed to "share sensory perception and decision-making among themselves" or with a human operator.⁴⁹ Finkelstein and Davis also coined the term "Walk n' Roll," which describes how a foot patrol police officer could be teamed with an APV to provide "superior community-centered" policing.⁵⁰

The research on APVs is in its infancy and will continue to expand in the coming years as researchers are only beginning to realize the potential benefits of the technology to the law enforcement community. The majority of these studies are by researchers conducting autonomous and emerging vehicle technologies. While the overall literature does not address the benefits and limitations of the AVP, assumptions can be drawn from

⁴⁵ Robert Finkelstein and Rob Davis, *Autonomous Cars for Law Enforcement* (Washington, DC: Police Foundation, Potomac, MD: Robotic Technology Inc., 2017), <https://www.techcastglobal.com/wp-content/uploads/ckfinder/userfiles/files/White%20Paper%20Mod%201%20Autonomous%20Cars%20Law%20Enforcement%202%20March%2017.pdf>, 1.

⁴⁶ Finkelstein and Davis, 5.

⁴⁷ Finkelstein and Davis, 5.

⁴⁸ Finkelstein and Davis, 6.

⁴⁹ Finkelstein and Davis, 6.

⁵⁰ Finkelstein and Davis, 8.

the research as to how the technology can be utilized. Further studies are needed to understand fully the complexity of the AVP and its impact on law enforcement agencies.

2. Complementary Technologies

The first use of a UAS was by the military for “dull, dirty, or dangerous” missions that put human pilots at a disadvantage or at risk during flight operations.⁵¹ The majority of the early literature discusses how a UAS can be controlled remotely by a ground operator or flown fully autonomously and the benefits of each. Within the last decade, the opportunities for the UAS have been realized by law enforcement agencies and the entire homeland security enterprise. The literature generally agrees that border security within the United States can be bolstered by the use of UAS platforms, but Christopher Bolkcom, writing in 2004, was one of the first to recognize the potential.⁵² Bolkcom worked as a specialist in military aviation for the Congressional Research Service. In addition to his work on the UAS, he has researched how air power influences counterinsurgency operations and how enemy defensive systems are effectively suppressed. His research recognizes how the UAS can benefit law enforcement agencies by filling a gap in border surveillance and security. Bolkcom identifies that a UAV “can provide precise and real-time imagery to a ground control operator, who would then disseminate that information so that informed decisions regarding the deployment of border patrol agents can be made quickly.”⁵³ Bolkcom’s idea has become a reality as the Customs and Border Protection (CBP) is testing the use of the UAS today.⁵⁴

Rachel Finn and David Wright have also taken Bolkcom’s research a step further by arguing that UAS platforms can be used for “safety inspections, perimeter patrols

⁵¹ Adam C. Watts, Vincent G. Ambrosia, and Everett A. Hinkley, “Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use,” *Remote Sensing* 4, no. 6 (June 8, 2012): 1671–92, <https://doi.org/10.3390/rs4061671>.

⁵² Christopher Bolkcom, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*, CRS Report No. RS21698 (Washington DC: Congressional Research Service, 2004), 7.

⁵³ Bolkcom, 3.

⁵⁴ Customs and Border Protection, “CBP to Test the Operational Use of Small Unmanned Aircraft Systems in 3 U.S. Border Patrol Sectors” (press release, September 14, 2017), <https://www.cbp.gov/newsroom/national-media-release/cbp-test-operational-use-small-unmanned-aircraft-systems-3-us-border>.

around prisons and thermal imaging to check for cannabis being grown in roof lofts.”⁵⁵ Finn and Wright work for the London-based company Trilateral Research, which conducts research on advanced technologies. While the majority of their research focuses on how advanced technologies have or will impact Europe, their 2012 article on surveillance, ethics, and privacy identifies several key considerations for U.S. law enforcement agencies. They point out that UAS technology has the ability to employ wireless sensor networks to check for the growth of illegal drugs while also using separate sensors, such as license plate readers, to scan the license plates of speeding drivers.⁵⁶ Finn and Wright also discuss how the UAS used by law enforcement agencies for surveillance, will affect privacy and other civil liberties in both the United States and the United Kingdom. U.S. law enforcement understand the concern over privacy; thus, they have messaged the public that “that they will not be spied upon by these unmanned drones.”⁵⁷

Adam Watt, Vincent Ambrosia, and Everett Hinkley’s article stands out among the wireless sensor network sources, as it discusses the benefits of using a UAS in great detail.⁵⁸ Watt, Ambrosia, and Hinkley are environmental researchers specializing in interdisciplinary ecology. Their 2012 research article examines how a wireless sensor system can be used on a UAS for scientific research in remote locations. While they do not discuss the use of these sensor systems by law enforcement agencies, they identify how UAS platforms can be fitted with “simplified cameras or streaming video cameras in either daylight (color or B/W) or infrared (B/W) video.”⁵⁹ Their article is extremely valuable, as it provides a more in-depth analysis than other sources of how sensor systems can be used successfully in civil applications.

⁵⁵ Rachel L. Finn and David Wright, “Unmanned Aircraft Systems: Surveillance, Ethics and Privacy in Civil Applications,” *Computer Law & Security Review* 28, no. 2 (April 1, 2012): 184–94, <https://doi.org/10.1016/j.clsr.2012.01.005>.

⁵⁶ Finn and Wright, 188.

⁵⁷ Finn and Wright, 191.

⁵⁸ Watts, Ambrosia, and Hinkley, “Unmanned Aircraft Systems in Remote Sensing,” 1673.

⁵⁹ Watts, Ambrosia, and Hinkley, 1678.

A general consensus in the literature states that a wireless sensor network can be applicable and beneficial to law enforcement agencies. However, Terry Bisbee and Daniel A. Pritchard, writing in 1997, were some of the first teams to identify the potential. Bisbee and Pritchard identify how specific wireless sensors “can solve many security assessment problems associated with the protection of high-value assets at military bases, secure installations, or commercial facilities.”⁶⁰ Their research also demonstrates how thermal imagers can be used for surveillance during low light maneuvers without additional lighting.⁶¹ Bisbee and Pritchard worked for Sandia National Laboratories and have conducted several research studies on nonproliferation and emerging military technologies over the last two decades. While their focus was on researching and developing military technologies, they recognized how law enforcement agencies could benefit from thermal imagers due to the rapid development and greater accessibility of the technology.⁶² They also determined that a “vehicle mounted thermal imager” could be used by civilian law enforcement agencies. This application has been realized by law enforcement agencies today with the advanced use of FLIR (forward-looking infrared) devices.⁶³

Ferris et al. conducted early research on the practicality of fusing two sensor networks to solve the problem of concealed weapons detection.⁶⁴ Ferris et al. determined that by combining infrared and millimeter-wave technologies, a wireless sensor platform could be used as a force multiplier for law enforcement agencies.⁶⁵ Ferris et al. described the force multiplier as the “fusion of sensors with complementary capabilities.”⁶⁶ While

⁶⁰ Terry L. Bisbee and Daniel A. Pritchard, “Today’s Thermal Imaging Systems: Background and Applications for Civilian Law Enforcement and Military Force Protection,” in *Proceedings IEEE 31st Annual 1997 International Carnahan Conference on Security Technology* (Canberra, ACT, Australia, Australia, 1997), 202–8, <https://doi.org/10.1109/CCST.1997.626270>.

⁶¹ Bisbee and Pritchard, 1.

⁶² Bisbee and Pritchard, 1.

⁶³ “Thermal Imaging, Night Vision and Infrared Camera Systems,” FLIR Systems, accessed September 10, 2018, <https://www.flir.com/>.

⁶⁴ Ferris et al., “Sensors for Military Special Operations and Law Enforcement Applications,” in *Proceedings of SPIE*, vol. 3062 (June 20, 1997): 173–180, <https://doi.org/10.1117/12.276674>.

⁶⁵ Ferris et al., 177.

⁶⁶ Ferris et al., 177.

they only focused on the capability of two sensors and solving one problem, this research is the foundation for the application of a multilayered law enforcement wireless sensor network. Additionally, Ferris et al. discussed the practicality of using both active and passive sensors to detect concealed weapons. Their research determined both types of sensors would be successful when combined together, as a “synergistic union” would be created to detect concealed weapons.⁶⁷

Ian F. Akyildiz, Tommaso Melodia, and Kaushik R. Chowdhury have taken the research of Ferris et al. a step further by arguing that wireless sensor networks could be used to “store, process in real-time, correlate, and fuse multimedia data originated from heterogeneous sources.”⁶⁸ Their research identified that “with rapid improvements and miniaturization in hardware,” a network of wireless sensor devices could be used together to retrieve “video and audio streams, still images, and scalar sensor data from the physical environment.”⁶⁹ Their examination of wireless sensor networks was critical in furthering law enforcement development of the technology to thwart criminal activity. They point out that wireless sensor technologies will support numerous law enforcement functions, such as “surveillance” and “traffic monitoring and enforcement.”⁷⁰ Specifically, they concluded that a network of sensors could be used to “enhance and complement existing surveillance systems against crime and terrorist attacks.”⁷¹ Furthermore, they determined that a wireless sensor network could be used to “detect violations and transmit video streams to law enforcement agencies to identify the violator.”⁷² This idea of a wireless sensor network used as a force multiplier by law enforcement agencies is now recognized by several sources as an instrumental platform, which can be utilized in many applications.

⁶⁷ Ferris et al., 177.

⁶⁸ Ian F. Akyildiz, Tommaso Melodia, and Kaushik R. Chowdhury, “Wireless Multimedia Sensor Networks: Applications and Testbeds,” in *Proceedings of the IEEE* 96, no. 10 (October 2008): 1588–1605, <https://doi.org/10.1109/JPROC.2008.928756>.

⁶⁹ Akyildiz, Melodia, and Chowdhury, 1588.

⁷⁰ Akyildiz, Melodia, and Chowdhury, 1588.

⁷¹ Akyildiz, Melodia, and Chowdhury, 1591.

⁷² Akyildiz, Melodia, and Chowdhury, 1591.

The article written by Du et al. stands out among the wireless sensor network sources, as it explores the benefits of using automatic license plate readers (ALPR) in great depth.⁷³ Du et al. discuss the specific benefits of using this sensor and conclude that it plays a significant role for law enforcement agencies, such as in toll collection, traffic and parking enforcement, and road traffic monitoring.⁷⁴ Their research is relevant to wireless sensor networks and its future capabilities, as it studies the pros and cons of ALPR systems over the last few decades. Additionally, their research categorizes existing license plate extracting methods that provide law enforcement agencies with a “systematic survey” of ALPR research upon which to draw.⁷⁵ Du et al. also determined that “an effective ALPR system should have the ability to deal with multistyle plates, e.g., different national plates with different fonts and different syntax.”⁷⁶ Until this discovery, little research had addressed this issue, as most ALPR systems do not have this capability. Even though their research primarily focused on APLR systems, it can be applied to other wireless sensors. Comparisons can be drawn in terms of the pros and cons to forecast future research for other sensors. Du et al. acknowledge that more ALPR research is needed and should be focused on future technologies, such as video-based ALPR techniques and high definition plate image processing.⁷⁷

Ericson et al., and Divyarajsinh N. Parmar and Brijesh B. Mehta have explored other uses for wireless sensor networks. Ericson et al., writing in 2014 for the National Institute of Justice (NIJ) sensor, surveillance, and biometric technologies (SSBT) Center of Excellence (CoE), identified a technological need for first responders to “sense the presence of persons through visually obscure barriers.”⁷⁸ They recognized that the

⁷³ Shan Du et al., “Automatic License Plate Recognition (ALPR): A State-of-the-Art Review,” in *IEEE Transactions on Circuits and Systems for Video Technology* 23, no. 2 (February 2013): 311–25, <https://doi.org/10.1109/TCSVT.2012.2203741>.

⁷⁴ Du et al., 311

⁷⁵ Du et al., 313.

⁷⁶ Du et al., 319.

⁷⁷ Du et al., 322.

⁷⁸ Lars Ericson et al., “Through-the-Wall Sensors (TTWS) for Law Enforcement: Use Case Scenarios (Version 1.3),” National Criminal Justice Reference Service, 1, April 24, 2014, <https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=268796>.

technology needed for this endeavor was through-the-wall sensors (TTWS). Specifically, they determined that the use of TTWS would enhance situational awareness for law enforcement personnel and firefighters during tactical operations.⁷⁹ These tactical operations would include anything from rescue operations to building clearances.⁸⁰ Their report is significant, as it “aims to educate practitioners on possible use-case scenarios and aid in evaluation, acquisition, and training related to deployed TTWS.”⁸¹ Parmar and Mehta, on the other hand, take a much more comprehensive look at wireless sensor networks, specifically, facial recognition methods and applications. While they acknowledge that facial recognition systems have been around for nearly 50 years, they determined that the technology still presents a challenge for law enforcement agencies in the field of image analysis and the security of information.⁸² Their article is extremely valuable, as it provides an inclusive look at facial recognition techniques, such as the holistic and hybrid matching methods.⁸³ This article is a much more in-depth analysis than other sources of how biometric systems can be used in correlation with different matching methods.

A strong consensus in the literature reveals several law enforcement benefits in utilizing wireless network sensors; however, concerns about their vulnerabilities have been raised. Virmani et al. articulate these concerns in their 2014 article that focused on “routing attacks in wireless sensor networks.”⁸⁴ Virmani et al. determined that “wireless sensor networks are susceptible to a variety of potential attacks which obstructs the normal operations of the network.”⁸⁵ They identified that both passive and active attacks could bring down a wireless sensor network.⁸⁶ Their research is important to law

⁷⁹ Ericson et al., 1.

⁸⁰ Ericson et al., 1.

⁸¹ Ericson et al., 1.

⁸² Divyarajsinh N. Parmar and Brijesh B. Mehta, “Face Recognition Methods & Applications,” Cornell University, 84–86, March 3, 2014, <http://arxiv.org/abs/1403.0485>.

⁸³ Parmar and Mehta, 84.

⁸⁴ Deepali Virmani et al., “Routing Attacks in Wireless Sensor Networks: A Survey,” Cornell University, 1, May 29, 2014, <http://arxiv.org/abs/1407.3987>.

⁸⁵ Virmani et al., 1.

⁸⁶ Virmani et al., 2.

enforcement agencies, as it identifies three categories of passive attacks against privacy: eavesdropping, traffic analysis, and camouflage. This determination will assist law enforcement agencies and future researchers in developing counter measures to an attack on wireless sensor networks.

In addition to wireless network sensor vulnerability, legal concerns are associated with the technology. David J. Roberts and Meghann Casanova, writing in 2012, researched the legal considerations revolving around the ALPR. While a specific ALPR court case has not been litigated in the United States, the “capture, storage and retrieval of ALPR data” might promote legal and privacy concerns by the public.⁸⁷ Roberts and Casanova studied court cases that “reference the variety of evolving technologies that increasingly enable law enforcement to track and record the movement of persons and vehicles without requiring the installation of special tracking devices.”⁸⁸ Their examination of court cases established that more research would be needed to determine how ALPR data would be viewed and interpreted by the courts. However, their recommendations for law enforcement agencies were essential to the future deployment of the ALPR. They acknowledged that “ALPR technology is a significant tool,” but it must be accompanied by a “comprehensive agency policy” that addresses the deployment and objectives of the stored data.⁸⁹ This research is crucial, as it crafts a strategy that can be applied to other wireless network sensors utilized by law enforcement agencies.

The research on wireless sensor networks and technology is a rich field, as many studies have taken place over the last several years. The majority of these studies are by researchers conducting research on a specific wireless sensor technology that can be applied to other technologies. While the overall literature interprets the benefits and concerns of these individual networks, a comprehensive law enforcement wireless network study has not been performed but may be beneficial for this research.

⁸⁷ David J. Roberts and Meghann Casanova, “Automated License Plate Recognition (ALPR) Use by Law Enforcement: Policy and Operational Guide, Summary,” 10, TRID, August 2012, <https://trid.trb.org/view/1223373>.

⁸⁸ Roberts and Casanova, 9.

⁸⁹ Roberts and Casanova, 10.

D. RESEARCH DESIGN

The research in this thesis evaluated current AV technology to extrapolate the benefits and consequences of APV technology. Additionally, this thesis evaluated complementary technology and its impact on law enforcement personnel. Ultimately, the purpose of this thesis is to assess the impact APV technology has on the role of law enforcement officers and its effect on law enforcement staffing levels.

1. Data Sources

Since APV technology is in its infant stages, information has come mainly from industry publications, news reports, and technology blogs. However, data sources on AV technology can be used to draw comparisons. This data comes from existing literature including relevant academic sources and legal journals. UAS and wireless sensor network technologies and information comes from sources, such as professional journals, government reports, research from experts within the field of sensor networks, and official U.S. federal agency websites.

2. Analytical Steps

This research first examines AV technology to establish a baseline understanding of how this technology can apply to the APV. This study then focuses on complementary technologies, which make up the foundation of the APV platform. These technologies have been in use by the military and law enforcement agencies for several years and will provide insight into the future applicability of the APV in the law enforcement community. Once the applicability of the APV and complementary technologies has been discussed, this thesis extrapolates the benefits and concerns of APV implementation. Finally, the impact of APV technology on the future mission of the law enforcement officer is examined using scenario analysis. These scenarios include the following:

- Traffic stops
- Police pursuits
- Calls for service/response time

- Fugitive searches
- Community policing

These scenarios are not comprehensive but provide the most relevant examples of how the APV may impact the future role of the law enforcement officer. The findings from these scenarios are cross-referenced with the benefits and concerns of APV implementation for comparison. The findings section includes a general discussion of lessons learned from these scenarios, including potential unintended consequences of APV implementation.

3. Output

The output of this study lends insight to public safety executives on the changing roles, mission, and tasks law enforcement officers may encounter as a result of APV implementation, which is accomplished by examining emerging AV technologies and analyzing plausible future scenarios. This thesis gives the reader an understanding of the potential unintended consequences of APV implementation and its impact on the law enforcement officer.

E. CHAPTER SUMMARY

Technological innovations are changing the way law enforcement agencies operate on a daily basis. While it may have been unimaginable a few years ago, technologies, such as the UAS, augmented reality, and biometrics have manifested, forever changing law enforcement. Additionally, emerging technologies, such as big data, analytics, the Internet of things (IoT), and artificial intelligence are trends that that will likely become more apparent in law enforcement agencies in the next few years.⁹⁰ The deployment of emerging technologies by law enforcement agencies is not stopping, but only gaining momentum. For sustained success, law enforcement agencies must

⁹⁰ Hollywood et al., *Emerging Technology Trends and Their Impact on Criminal Justice*, 1.

recognize the “technologies and practices with the most potential for improving public safety.”⁹¹

The APV is an evolving technology that can substantially improve public safety; yet, the impacts on the law enforcement officer are unknown. The next chapter provides background information on the APV. The chapter explores existing AV technology, as well as an overview of how the APV is currently being developed and deployed to gain a perspective on how law enforcement agencies may employ the technology.

⁹¹ Hollywood et al., 1.

II. AUTONOMOUS POLICE VEHICLE OVERVIEW

A. AUTONOMOUS VEHICLE BACKGROUND

The idea of AVs gained worldwide attention in 1939 at the World Fair when General Motors displayed a Futurama exhibit and proclaimed cars would soon drive themselves.⁹² Technology continued to advance over the next several years, and in 1977, the first truly autonomous car was revealed to the world in Japan at the Tsukuba Mechanical Engineering Laboratory.⁹³ The Japanese vehicle was designed with two working cameras, used analog computer technology, and was capable of speeds of nearly 19 mph.⁹⁴ In 2009, 70 years after the Futurama exhibit, Google announced a self-driving car project would be tested on California roadways. Google's self-driving car project has AVs that have been driven over seven million miles in six states and 25 cities, far more than any other autonomous vehicle to date.⁹⁵ Google claims the technology in its AVs has evolved from student driver status to that of a more experienced licensed everyday driver over the last seven years.⁹⁶

In addition to Google's self-driving car project, Tesla has been testing autonomous vehicles that have amassed over one billion miles in Autopilot since 2015.⁹⁷ Audi, BMW, GM, Nissan, Volvo, Bosch, Daimler, and Continental are just some of the other auto manufactures investing in AV technology.⁹⁸ Startups, such as May Mobility and Drive.ai, as well as the ride-sharing companies, Uber and Lyft, are also entering the AV market.⁹⁹ Most of these companies already have an AV that can navigate at slow

⁹² Tom Vanderbilt, "Autonomous Cars through the Ages," WIRED, February 6, 2012, <https://www.wired.com/2012/02/autonomous-vehicle-history/>.

⁹³ Vanderbilt.

⁹⁴ Vanderbilt.

⁹⁵ Waymo, "On the Road."

⁹⁶ Johana Bhuiyan, "After Two Million Miles, Google's Robot Car Now Drives Better than a 16-Year-Old," Recode, October 5, 2016, <https://www.recode.net/2016/10/5/13167364/google-self-driving-cars-2-million-miles>.

⁹⁷ MIT Human-Centered AI, "Tesla Autopilot Miles."

⁹⁸ Mosquet et al., "Revolution in the Driver's Seat."

⁹⁹ Davies, "The Wired Guide to Self-Driving Cars."

speeds.¹⁰⁰ By 2021, almost all these automotive manufacturers will be able to display AVs “capable of navigating city streets at casual speeds along firmly fixed routes.”¹⁰¹

Worldwide, roughly 1.4 billion cars are on the road today; yet, with the increasing technological advances, it seems only conceivable that it is a matter of time before fully autonomous vehicles replace all these vehicles.¹⁰² Some conservative estimates say it would take until 2035 at the earliest before half of the vehicles on the road in the United States represented fully autonomous vehicles, while other experts predict that by the year 2021, 100,000 self-driving cars will be on the roadway.¹⁰³ Either way, AVs will become a reality, as law enforcement agencies must understand how to leverage this technology for sustained success.

1. Levels of Autonomous Vehicle Technology

For purposes of this thesis, a clear definition is first needed to establish what constitutes an AV. According to the *Dictionary of Information Science and Technology*, the definition of an unmanned AV is, “a machine that can move through the terrain intelligently and autonomously without the need for any human intervention.”¹⁰⁴ Several technology journals have defined AVs as well, and the common theme is that an AV is a vehicle driven by a computer without the aid of a human operator.¹⁰⁵ The NHTSA has taken the definition of an AV a step further and has broken down the levels of automation. The NHTSA has broken down AV into the following six levels, as shown in Figure 1.

¹⁰⁰ David Welch and Elisabeth Behrmann, “Who’s Winning the Self-Driving Car Race?,” May 7, 2018, Bloomberg, <https://www.bloomberg.com/news/features/2018-05-07/who-s-winning-the-self-driving-car-race>.

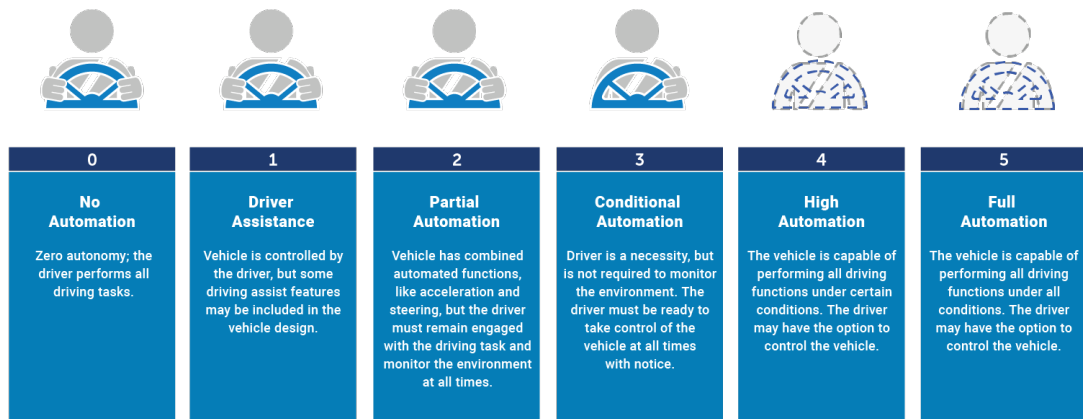
¹⁰¹ Welch and Behrmann.

¹⁰² “Registered Vehicles Data by Country,” Global Health Observatory, World Health Organization, last updated November 30, 2015, <http://apps.who.int/gho/data/node.main.A995>.

¹⁰³ Eisenstein, “Self-Driving Cars Take to the Road.”

¹⁰⁴ Mehdi Khosrow-Pour, *Dictionary of Information Science and Technology*, 2nd ed. (Hershey, PA: IGI Global, 2012), 913.

¹⁰⁵ “Autonomous Vehicle Definition,” PC Magazine Encyclopedia, accessed September 28, 2017, <https://www.pcmag.com/encyclopedia/term/57132/autonomous-vehicle>.

Figure 1. Levels of Vehicle Automation¹⁰⁶

Essentially, Levels 0 through 2 require a human driver to maintain control of the vehicle, while Levels 3 through 5 have some degree of an automated driving system that monitors the driving environment.¹⁰⁷ For purposes of this thesis, anything from conditional automation (Level 3) to full automation (Level 5) is considered an AV, as it is considered to be the minimal baseline technology of the APV.

2. Autonomous Vehicle Technologies

The AV uses a combination of sensor technologies to scan the roadway looking for other vehicles, as well as objects. The sensor technologies that make up the AV platform include rear and 360-degree cameras, radar, light detection and ranging (LIDAR), and ultrasonic and infrared sensors.¹⁰⁸ Several types of each of these sensors are located throughout the AV, which work together to monitor the driving environment. The AV cameras and radar sensors are a prerequisite for Level 1 and 2 vehicles and are

¹⁰⁶ Source: “Automated Vehicles for Safety,” NHTSA, accessed September 28, 2017, <https://www.nhtsa.gov/technology-innovation/automated-vehicles>.

¹⁰⁷ NHTSA.

¹⁰⁸ Gert Rudolph and Uwe Voelzke, “Three Sensor Types Drive Autonomous Vehicles,” *Sensors Magazine*, November 10, 2017, <https://www.sensorsmag.com/components/three-sensor-types-drive-autonomous-vehicles>, 2.

required for further levels of automation.¹⁰⁹ LIDAR sensors enable autonomous driving greater than a Level 3.¹¹⁰ Figure 2 provides a further description of the technologies.

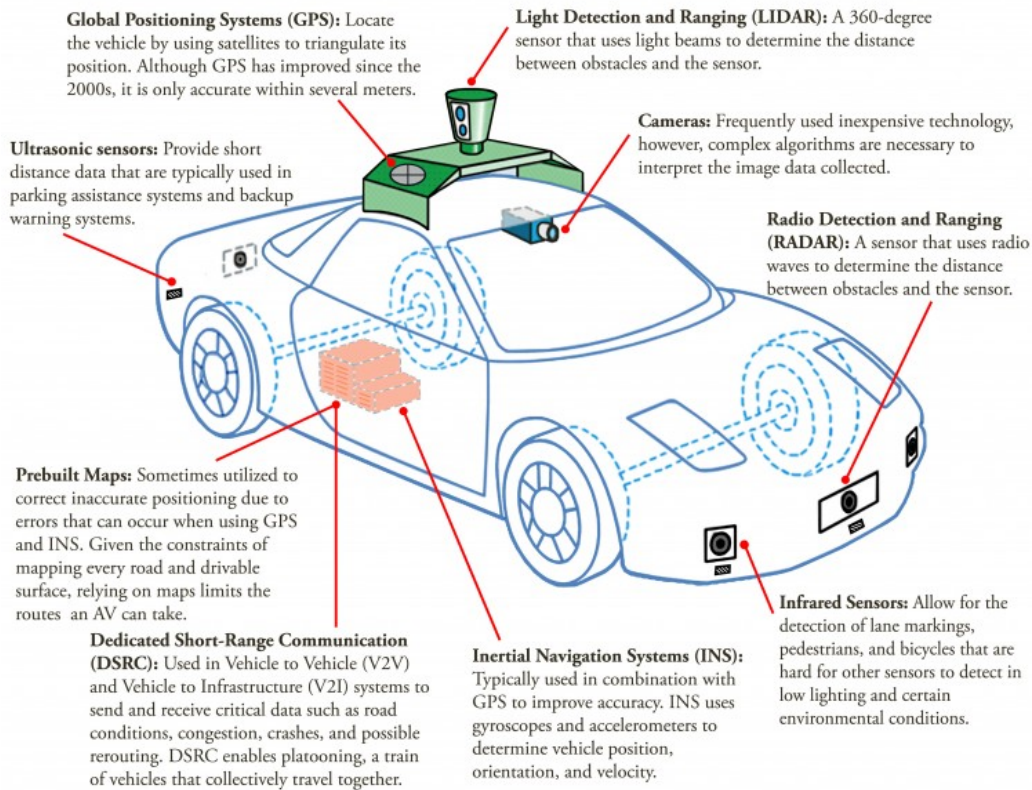


Figure 2. AV Technologies¹¹¹

3. Potential Benefits

a. *Reduction in Collisions*

In the United States, 94% of all traffic collisions are the result of human error.¹¹² In 2014, about 33,500 people died in the United States due to a traffic collision, while 2.3

¹⁰⁹ Rudolph and Voelzke, 2.

¹¹⁰ Rudolph and Voelzke, 5.

¹¹¹ Source: "Autonomous Vehicles Factsheet," Center for Sustainable Systems, University of Michigan, August 2018, <http://css.umich.edu/factsheets/autonomous-vehicles-factsheet>.

¹¹² Christian Denmon, "How Self Driving Cars Impact Traffic Law Enforcement," Denmon Pearlman, July 4, 2017, <https://denmon.lawyer/criminal-law/self-driving-cars/>.

million were injured.¹¹³ Vehicles driven by a human operator accounted for one fatality for every 90 million miles driven and 4.2 traffic collisions per one million miles.¹¹⁴ For every fatality that occurs in the United States, more than 100 people are treated in emergency rooms, which equates to an annual cost of \$33 billion.¹¹⁵ Annually, traffic collisions cost the United States economy more than \$200 billion.¹¹⁶ These statistics are staggering; however, the AV has already begun to make U.S. roads safer. Since 2009, only 14 traffic collisions and two fatalities have occurred in over 132 million miles driven by AVs.¹¹⁷ This number equates to 3.2 traffic collisions per one million miles. The AV could reduce accident rates by 90%, and ultimately save \$190 billion.¹¹⁸ This reduction in traffic collisions means fewer fatalities and fewer collisions investigated by police officers.

b. More Time for Drivers (Passengers)

Once the AV goes mainstream, previous automobile drivers become passengers. This change can make users of the AV much more efficient and free up as much as 50 minutes a day to work, relax, or play.¹¹⁹ The time saved globally by users equates to roughly one billion hours, “equivalent to twice the time it took to build the Great Pyramid of Giza.”¹²⁰ If time is money, AV technology may be the next big bonus.

¹¹³ Safety Team, “How Safe Are Self-Driving Cars?,” Safer America, November 7, 2016, <http://safer-america.com/safe-self-driving-cars/>.

¹¹⁴ Denmon, “How Self Driving Cars Impact Traffic Law Enforcement.”

¹¹⁵ “Motor Vehicle Crash Injuries,” Centers for Disease Control and Prevention, October 7, 2014, <https://www.cdc.gov/vitalsigns/crash-injuries/index.html>.

¹¹⁶ Michele Bertonecello and Dominik Wee, “Ten Ways Autonomous Driving Could Redefine the Automotive World,” McKinsey, accessed January 14, 2019, <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world>.

¹¹⁷ Denmon, “How Self Driving Cars Impact Traffic Law Enforcement.”

¹¹⁸ Bertonecello and Wee, “Ten Ways Autonomous Driving Could Redefine the Automotive World.”

¹¹⁹ Bertonecello and Wee.

¹²⁰ Bertonecello and Wee.

c. Eliminate Traffic Congestion

AVs will be able to coordinate with each other and essentially eliminate the ripple effect in traffic and intersections that results in reduced traffic jams. A University of Illinois study in 2017 suggested that a single AV in a group of 20 vehicles could reduce traffic congestion by 50%.¹²¹ The elimination of traffic jams and congestion will contribute to a reduction in traffic collisions but may also minimize traffic stops by law enforcement. In the United States, approximately 800,000 drivers are pulled over a day by police officers, and approximately 112,000 of those drivers receive a speeding ticket.¹²² Annually, over 41,000,000 people receive speeding tickets generating roughly \$6,232,000,000 in revenue for local municipalities.¹²³ Joseph A. Schafer, the criminal justice department head at Southern University, believes the traffic stop may even be eliminated. Schafer states, “I think you would see the end of the traffic stop,” once AVs dominate our roadways.¹²⁴ Schafer also asserts that AVs, “radically changes police-public encounters,” and it will be pointless to issue a ticket to the occupants of self-driving cars.¹²⁵ Schafer adds, “Some things we regulate may not be enforced in the same way, such as speed limits. There may not be speed limits depending on the ways cars are programmed. Speeding itself may not even be an offense.”¹²⁶

4. AV State of Readiness

A 2018 autonomous vehicle readiness index study (AVRI) by KPMG provides an in-depth analysis of how prepared countries are for AV technological advancement.¹²⁷ Of

¹²¹ Shumo Cui et al., “Stabilizing Traffic Flow via a Single Autonomous Vehicle: Possibilities and Limitations,” in *IV 2017—28th IEEE Intelligent Vehicles Symposium* (2017): 1336–41, <https://doi.org/10.1109/IVS.2017.7995897>.

¹²² “Driving Citation Statistics,” Statistic Brain Research Institute, accessed September 29, 2017, <http://www.statisticbrain.com/driving-citation-statistics/>.

¹²³ Statistic Brain Research Institute.

¹²⁴ Patrick Sisson, “How Will Driverless Cars Change Street Policing?,” *Curbed*, February 10, 2017, <https://www.curbed.com/2017/2/10/14581254/cops-law-enforcement-driverless-cars-autonomous-vehicles>.

¹²⁵ Sisson.

¹²⁶ Sisson.

¹²⁷ Richard Threlfall, “2018 Autonomous Vehicles Readiness Index,” KPMG, April 13, 2018, <https://home.kpmg.com/xx/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html>.

the 20 countries researched in the study, the Netherlands ranks first overall, while in contrast, the United States ranks third. The study rates countries “according to four pillars that are integral to a country’s capacity to adopt and integrate autonomous vehicles.”¹²⁸ The pillars include “policy and legislation, technology and innovation, infrastructure, and consumer acceptance.”¹²⁹ “According to the study, the Netherlands is the clear leader in the first *Autonomous Vehicles Readiness Index*. It is within the top four of each of the four pillars... and provides an AV readiness for others to follow.”¹³⁰ The Netherlands is the perfect case study to understand the future implications of APV implementation, as the country “is driving the future of smart mobility” in everything from energy storage to traffic solutions.¹³¹

a. Policy and Legislation

A significant advantage the Dutch have over the United States is how quickly their federal government passes and implements AV legislation. In the last four years alone, the Dutch have implemented several successful AV policies. In June 2014, the Netherlands announced it would allow the large-scale testing of the AV on Dutch roads and wanted “to position itself as an international leader and testing country.”¹³² In January 2015, a proposal to extend exemption rules to large-scale testing was approved by the Council of Ministers.¹³³ This proposal allowed manufacturers to receive an exemption from the Road Transport Agency (RDW) but a driver was still needed inside the vehicle to take over if necessary.

¹²⁸ Threlfall.

¹²⁹ Threlfall.

¹³⁰ Threlfall.

¹³¹ “KPMG Ranks the Netherlands No 1 in Autonomous Vehicles Readiness,” Netherlands Foreign Investment Agency, January 17, 2018, <https://investinholland.com/kpmg-ranks-the-netherlands-no-1-in-autonomous-vehicles-readiness/>.

¹³² Chris Hottentot, Veronique Meines, and Mike Pinckaers, *Experiments on Autonomous and Automated Driving: An Overview 2015* (The Hague, Netherlands: ANWB, 2015), 5, https://www.anwb.nl/binaries/content/assets/anwb/pdf/over-anwb/persdienst/rapport_inventarisatie_zelfrijdende_auto.pdf.

¹³³ Hottentot, Meines, and Pinckaers, 5.

b. Technology and Innovation

AVs are configured with multiple processors that employ numerous sensors with the capability to talk to other computers. The AV is essentially a cog in the IoT wheel. These highly technical machines are why automakers in Detroit and Germany are partnering with technology companies in Silicon Valley. The United States has 163 AV companies headquartered within its borders, the highest of any other country. However, the Netherlands is only slightly behind the United States. The KPMG study ranks the Netherlands fourth overall on technology and innovation, due predominately to the fact that the Netherlands has the highest percentage usage of electric vehicles of any other country in the study.¹³⁴ The Dutch also have a strong telecommunications network and AV testing capabilities. The country's AV industry supports 400 companies with 45,000 workers creating over 20 billion Euros in net sales per year.¹³⁵

c. Infrastructure

For a country to have a successful AV program, it must have a robust road and mobile network infrastructure, an area in which the Netherlands shines. According to the KPMG study, the Dutch ranked number one out of the 20 countries researched. The World Economic Forum and the World Bank have also rated the Dutch infrastructure the best in the world.¹³⁶ The use of electric vehicles is an indicator of AV readiness in a country. Due to the large usage of electric vehicles, the Netherlands also has “the highest density of electrical vehicle charging points” in the world, with over 26,000 charging points available to the public.¹³⁷ To put this usage in perspective, this number is eight times more than Japan has for its entire road length.¹³⁸

¹³⁴ Threlfall, “2018 Autonomous Vehicles Readiness Index.”

¹³⁵ “How the Dutch Drive Mobility,” Netherlands Foreign Investment Agency, May 24, 2018, <https://investinholland.com/how-the-dutch-drive-mobility/>.

¹³⁶ Threlfall, “2018 Autonomous Vehicles Readiness Index.”

¹³⁷ Simon Alvarez, “Netherlands Ranks 1st in Autonomous Vehicle Readiness, U.S. Places 3rd,” *TESLARATI* (blog), January 25, 2018, <https://www.teslarati.com/netherlands-ranks-1st-autonomous-vehicle-readiness-kpmg-study/>.

¹³⁸ Threlfall, “2018 Autonomous Vehicles Readiness Index.”

d. Consumer Acceptance

The last piece of the AV puzzle is how quickly consumers are willing to accept AV technology. Consumers continue to be anxious about the safety of the AV, but overall, concerns are fading. In a 2018 poll, only 47 percent of U.S. consumers felt the AV would not be safe, compared to 74 percent in 2017.¹³⁹ It appears that the more transparent the government, auto manufactures, and technology companies are about AV technology, the more willing they will be to accept the automotive disruption.¹⁴⁰ The consumers in the Netherlands have accepted AV technology, as the country ranks second overall in consumer acceptance, slightly behind Singapore.¹⁴¹

B. AUTONOMOUS POLICE VEHICLE BACKGROUND

In addition to the Dubai Police Department's use of the APV, other entities are beginning to invest in the technology. In September 2017, the United States received a patent application from Motorola for a "mobile law enforcement communication system" level 5 autonomous vehicle.¹⁴² The technology to be utilized in the APV (facial recognition, fingerprint scanners, and a built-in breathalyzer) is already readily available.¹⁴³ The Motorola APV will operate without a law enforcement officer present and can read the suspect's Miranda rights and make phone calls to a lawyer or judge via videophone.¹⁴⁴ When a bail amount is reached for the criminal infraction, the APV allows the offender to swipe a credit card directly into the vehicle for payment.¹⁴⁵

¹³⁹ "Deloitte Study: Consumer Trust in Autonomous Vehicles on the Rise," Deloitte United States, accessed September 3, 2018, <https://www2.deloitte.com/us/en/pages/about-deloitte/articles/press-releases/2018-global-automotive-consumer-survey-press-release.html>.

¹⁴⁰ Jens Kaan, *User Acceptance of Autonomous Vehicles* (Delft, Netherlands: Delft University of Technology, 2017), 53.

¹⁴¹ Threlfall, "2018 Autonomous Vehicles Readiness Index."

¹⁴² Alex Marron, Anthony J. Suppelsa, and Barbara R. Doutre, Mobile law enforcement communication system and method, United States US10049419B1, filed September 6, 2017, and issued August 14, 2018, <https://patents.google.com/patent/US10049419B1/en?q=10049419>.

¹⁴³ "Is This Motorola Autonomous Police Car Patent the Real Robocop of Our Dystopian Future?" Autoweek, October 8, 2018, <https://autoweek.com/article/autonomous-cars/future-law-enforcement-motorola-patents-autonomous-police-car-0>.

¹⁴⁴ Marron, Suppelsa, and Doutre, Mobile law enforcement communication system and method.

¹⁴⁵ Marron, Suppelsa, and Doutre.

Ford Motor Company has taken Motorola's initial concept and advanced it further. In January 2018, Ford was issued a patent for an APV that could operate "in lieu of or in addition to human police officers."¹⁴⁶ The APV will be able to identify violations of traffic laws and automatically maneuver behind the offender to initiate a traffic stop.¹⁴⁷ While the APV is idle, "it may learn to park where violations of traffic can be viewed."¹⁴⁸ The APV will include sensors, navigation and mapping equipment, a traffic laws database, recording equipment, and devices to communicate with other AVs. The APV will also pull images from nearby surveillance cameras through wireless communication and extract data from government agencies to verify violations.¹⁴⁹ Figure 3 illustrates how the APV will be part of the larger IoT network.

¹⁴⁶ Ahmed et al., Autonomous police vehicle.

¹⁴⁷ Joe, "Ford Developing Autonomous Systems for Police Cars, Other Emergency Vehicles."

¹⁴⁸ Joe.

¹⁴⁹ Joe.

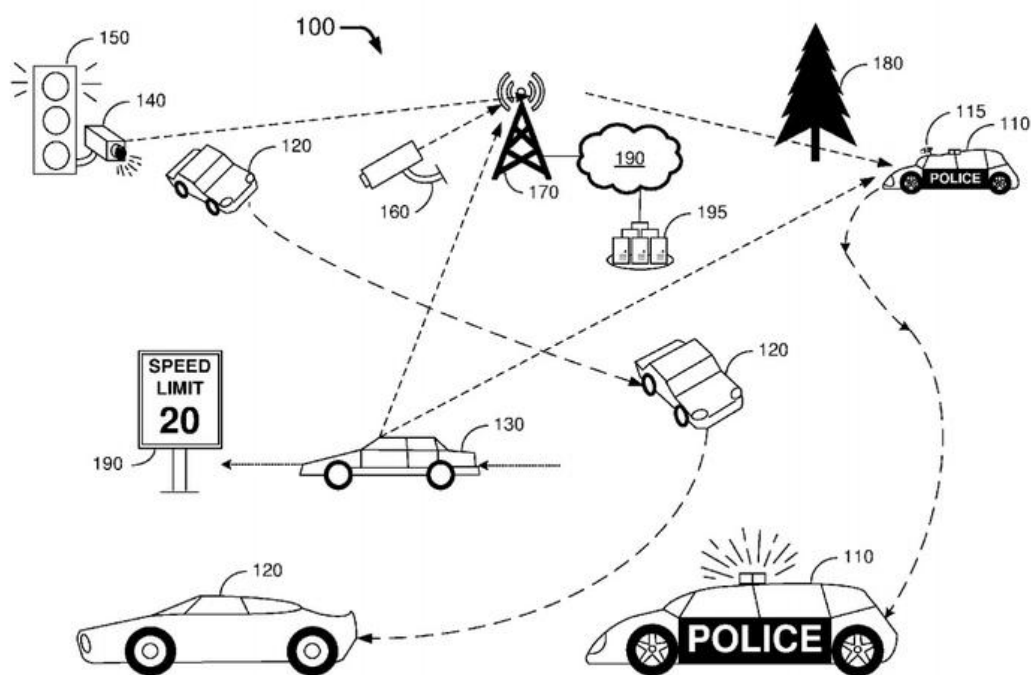


Figure 3. The Connected APV Network¹⁵⁰

The APV can drastically change how law enforcement agencies enforce laws, as the vehicles will be a part of a larger technology and information sharing system. In September 2014, the RAND Corporation brought together a group of law enforcement experts for the National Institution of Justice to “discuss how the criminal justice community can take advantage of (and reduce the risks from) emerging web technologies.”¹⁵¹ The panel presented several findings and identified 45 technology needs, such as “exploring the use of emerging internet of things (IoT) sensors in criminal justice.”¹⁵² In addition to discussing the AV as a top priority, the panel discussed the four other top needs of law enforcement. These needs are “virtual criminal record catalogs, better access to data for facial recognition identification, biomedical sensors for officers, and identification of officers in close proximity.”¹⁵³ The panel concluded that it would be

¹⁵⁰ Source: Joe.

¹⁵¹ Hollywood et al., Using Future Internet Technologies to Strengthen Criminal Justice, 1.

¹⁵² Hollywood et al., 2.

¹⁵³ Hollywood et al., 2.

imperative for law enforcement agencies to keep pace and leverage the emerging technologies for sustained success.¹⁵⁴ The APV will be able to address these four needs by incorporating emerging technologies into the AV platform. The APV will have technological capabilities that far supersede anything that can be performed by a human alone.

Another study was conducted by the Tech Policy Lab at the University of Washington, which has been working with the City of Seattle to assist them in planning and preparing for the AV.¹⁵⁵ The report identifies that one key challenge will be for law enforcement and emergency services to keep up with current AV technology.¹⁵⁶ The report identifies unique opportunities for law enforcement agencies to consider, such as the APV being used by law enforcement agencies to conduct surveillance of a person suspected in a crime.¹⁵⁷ This surveillance technique will be substantially cheaper to conduct for law enforcement without the added risk to the officer.¹⁵⁸ The APV can also be used to, “help locate and mark an accident scene or provide transportation for injured or unsafe drivers.”¹⁵⁹

C. CHAPTER SUMMARY

While the progression of the APV is still in its infancy in the United States, it has already been employed overseas by the Dubai Police Department and has been patented by Motorola and Ford. The APV has the ability to change significantly how law enforcement agencies employ their patrol vehicles. The APV will be a connected technology and a part of a larger information and sharing law enforcement network. The APV will utilize current AV technologies, but the entire platform will be much more sophisticated and include complementary technologies.

¹⁵⁴ Hollywood et al., 3.

¹⁵⁵ Tech Policy Lab, *Driverless Seattle; How Cities Can Plan for Automated Vehicles* (Seattle, WA: University of Washington, 2017), http://www.mobility-innovation-center.uwcomotion-sites.com/wp-content/uploads/2017/02/TPL_Driverless-Seattle_2017.pdf, 2.

¹⁵⁶ Tech Policy Lab, 15.

¹⁵⁷ Tech Policy Lab, 15.

¹⁵⁸ Tech Policy Lab, 15.

¹⁵⁹ Tech Policy Lab, 15.

The next chapter explores these complementary technologies, such as the UAS and wireless sensor networks. Complementary technologies are existing stand-alone technologies that will make up the foundation of the APV platform. The chapter spends time discussing how these complimentary technologies function as stand-alone systems to gain perspective on how they will function as part of the wider more sophisticated APV platform.

PAGE INTENTIONALLY LEFT BLANK

III. AUTONOMOUS POLICE VEHICLE PLATFORM— COMPLEMENTARY TECHNOLOGIES

The technologies included in this section are complementary technologies that will ultimately make up the completed platform of the APV. These technologies go above and beyond what will be included in the standard AV platform. These technologies include the UAS, thermal imagers, ALPRs, air sampling sensors, facial recognition, gunshot detection systems, and through-the-wall sensors. Each of these systems is readily available, as many have been used as stand-alone technologies by law enforcement agencies. This section identifies how each technology has impacted the law enforcement officer to understand what the implications may be when these technologies are used in conjunction with the wider, more sophisticated APV platform.

A. UNMANNED AIRCRAFT SYSTEM

The UAS is a similar technology to the APV in that it has similar law enforcement functions, capabilities, and missions. However, while the APV has yet to be realized, law enforcement agencies throughout the United States have been quick to adopt the UAS as usage has increased by 82% in 2017.¹⁶⁰ The first use of a UAS by a local or state law enforcement agency occurred in 2005, when the Irwin County Sheriff's Office in Georgia used a UAS during a search and rescue operation.¹⁶¹ The 14 years of use by law enforcement agencies provides context on the impact to law enforcement during that timeframe. Since the technologies are analogous in certain respects, comparisons can also be made on the impact to law enforcement officers utilizing the APV.

¹⁶⁰ Dan Gettinger, "Public Safety Drones: An Update," *Center for the Study of the Drone* (blog), May 28, 2018, <https://dronecenter.bard.edu/public-safety-drones-update/>.

¹⁶¹ Jonathon Weiss, "UAVs in Law Enforcement," *JonnyUAV*, February 7, 2018, <https://www.jonnyuav.com/single-post/2018/01/24/UAVs-in-Law-Enforcement>.

A recent report by the Centre for the Study of the Drone at Bard College reveals that at least 347 law enforcement agencies purchased a UAS between 2009 and 2017.¹⁶² The requisition of the UAS shows no sign of slowing down either. More drones were purchased in 2016 by law enforcement agencies than all the previous years combined.¹⁶³ The center estimated that over 900 public safety agencies, including police departments, fire departments, and emergency service departments are using a UAS.¹⁶⁴ By surveilling inaccessible roadways and locations, UAS deployment extends the reach of patrol officers.¹⁶⁵ As crimes are occurring, the UAS is able to “provide real-time information” to law enforcement personnel to help them critical assess the situation.¹⁶⁶ Law enforcement agencies are able to use the UAS in the sky to check for the growth of illegal drugs while also using separate sensors, such as ALPRs to scan the license plates of speeding drivers.¹⁶⁷ The UAS can be used to “capture video and images of crime as they occur, providing crucial evidence in future court proceedings.”¹⁶⁸ It can help law enforcement agencies better plan responses and save the lives of both officers and civilians. The fact is, sending in a UAS to investigate and observe a highly dangerous scenario is much safer for law enforcement, as the information it can provide is both faster and more reliable than sending in a squad of police officers.

The Department of Homeland Security’s (DHS’s) CBP began using the UAS in 2006.¹⁶⁹ The CBP may also have the most UAS law enforcement practical experience

¹⁶² Dan Gettinger, “Public Safety Drones,” Center for the Study of the Drone, April 2017, <http://dronecenter.bard.edu/public-safety-drones/>.

¹⁶³ Gettinger.

¹⁶⁴ John Seewer, “Law Enforcement Agencies Turning to Drones to Fight Crime,” PoliceOne, May 29, 2018, <https://www.policeone.com/police-products/Police-Drones/articles/475612006-Law-enforcement-agencies-turning-to-drones-to-fight-crime/>.

¹⁶⁵ Timothy Roufa, “Learn How Today’s Technology Will Transform Tomorrow’s Police,” The Balance Careers, updated December 1, 2018, <https://www.thebalancecareers.com/technologies-that-are-changing-the-way-police-do-business-974549>.

¹⁶⁶ Roufa.

¹⁶⁷ Finn and Wright, “Unmanned Aircraft Systems,” 188.

¹⁶⁸ Roufa, “Learn How Today’s Technology Will Transform Tomorrow’s Police.”

¹⁶⁹ Government Accountability Office, *Border Security: Additional Actions Needed to Strengthen Collection of Unmanned Aerial Systems and Aerostats Data*, GAO-17-152 (Washington, DC: Government Accountability Office, 2017), 5, <https://www.gao.gov/products/GAO-17-152>.

due to the Reform and Terrorism Prevention Act (Public Law 108-458), which directed the CBP to study the practicability of using the technology.¹⁷⁰ The technology utilized on the CBP's UAS has capabilities that supersede those of human border patrol agents. Each UAS is equipped with sensors that can identify an object on the ground as far away as 60,000 feet.¹⁷¹ It can also relay real time information to ground control operators so CBP agents can make decisions quickly and decisively. In late 2017, the CBP received approval to evaluate small unmanned aircraft systems (sUAS), which are even more technologically advanced than what is currently being used by the agency.¹⁷² The sUAS will enable CBP agents to provide "reconnaissance, intelligence, surveillance, tracking and acquisition" in areas deemed too high risk for agents.¹⁷³ The sUAS will be used in humanitarian operations in locating those in remote areas in need of medical aid.¹⁷⁴ The CBP will also be testing the sUAS to identify buildings and structures during an active shooting scenario to locate potential shooters or victims.¹⁷⁵ The integration of the UAS into the CBP's mission was a logical step because the technology could be used as a force multiple to allow fewer agents to be deployed in day-to-day operations.¹⁷⁶ Additionally, the UAS fills "a gap in current surveillance by improving coverage along remote sections of the U.S. borders."¹⁷⁷

B. THERMAL IMAGING SENSORS

Thermal imaging is a powerful technology that allows officers to see into the night, through darkness, fog, and dust. Thermal imaging sensors retain their clarity in any

¹⁷⁰ Chad C. Haddal and Jeremiah Gertler, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*, CRS Report No. RS21698 (Washington, DC: Congressional Research Service, 2010), 2, <http://www.dtic.mil/docs/citations/ADA524297>.

¹⁷¹ Haddal and Gertler, 3.

¹⁷² Customs and Border Protection, "CBP to Test the Operational Use of Small Unmanned Aircraft Systems in 3 U.S. Border Patrol Sectors."

¹⁷³ Customs and Border Protection.

¹⁷⁴ Customs and Border Protection.

¹⁷⁵ Mark Rockwell, "DHS Seeks Drones to Patrol the Border," Federal Computer Week, May 2, 2018, <https://fcw.com/articles/2018/05/02/dhs-border-drones.aspx>.

¹⁷⁶ Haddal and Gertler, *Homeland Security*, 4.

¹⁷⁷ Haddal and Gertler, 3.

lighting condition and are different from typical night vision cameras (NVCs). The NVC needs ambient light to operate while thermal imaging sensors detect and “measure thermal energy emitted from an object.”¹⁷⁸ This energy can be emitted from many objects that can create their own source of heat, such as humans, animals, engines, and machinery. Other objects, such as land, rocks, and vegetation are visible because they radiate heat at night after absorbing it from the sun during the day.¹⁷⁹ All these things are emitting thermal energy, which is observed by the sensors.

This technology has noticeably changed the way patrol officers work, which makes their job both easier and safer. A few examples of law enforcement use include locating fleeing vehicles in a pursuit, conducting building searches, conducting search and rescue operations, engaging in surveillance operations, and monitoring police perimeters during tactical operations. Thermal imaging technology has already affected routine law enforcement calls, such as a warehouse break in. Prior to thermal imaging technology, the officer was faced with two choices: finding and turning on the warehouse lights or walking around the warehouse waving their flashlights back and forth trying to locate the suspect. Neither of these two choices is ideal, as both expose the officers’ position while creating an unnecessary safety risk. However, the use of thermal imaging has permitted the officer to enter the warehouse, “see” the thermal energy emitted by the suspect, and safely identify their location. As a result, the officer now has the upper hand since the location of the suspect is known. The patrol officer can use other strategies to apprehend the suspect and proactively avoid a potential use of force situation; a clear example of how thermal imaging mitigates the risk to both the officer and the suspect in every day police work.

Thermal imaging is also helping patrol officers in the field in situations that seemed impossible just a few years ago. Law enforcement agencies have begun to use

¹⁷⁸ Dave Douglas, “Night Vision and Thermal Imaging,” March 27, 2012, <http://www.policemag.com/channel/technology/articles/2012/03/owning-the-night.aspx>.

¹⁷⁹ Douglas.

thermal imaging to collect evidence in assault and domestic violence cases.¹⁸⁰ The technology can be used as an “indicator” tool to identify evidence in these cases by looking at the surface temperature of the victims.¹⁸¹ This technology is helpful to the officer because thermal imagers can detect an asymmetrical pattern in a temperature range when comparing different parts of the body.¹⁸² The asymmetrical pattern would be an indicator of injuries incurred during an assault.

Commercial vehicle enforcement is another area in which thermal imaging is assisting the law enforcement officer. Thermal imaging technology has been used by law enforcement agencies in Kentucky to identify brake and tire violations on commercial vehicles.¹⁸³ The enforcement of these violations mitigates the number of collisions caused by brake or tire failure. The technology can be used to screen commercial vehicles approaching a weigh station so that these vehicles do not have to stop at the weigh station to be tested.¹⁸⁴ This technology thus decreases the time commercial vehicles are stopped for inspections and frees up valuable time for police officers that can otherwise be spent on visual commercial inspections.

While these applications are some of the most common law enforcement ones used for thermal imaging, the actual limits exist only in the patrol officer’s creativity. The police officer’s utilization of thermal imaging technology has clearly provided greater safety and effectiveness to help make any officer more efficient.

C. AUTOMATED LICENSE PLATE READERS

ALPRs are “mounted to the exterior of patrol cars” and use cameras to automatically capture and “analyze license plates on every vehicle...within their range of

¹⁸⁰ Brian Bennett, “Beneath the Surface,” Officer, September 16, 2016, <https://www.officer.com/investigations/article/12232472/are-thermal-cameras-the-next-step-in-law-enforcement-documentation-of-assault-injuries>.

¹⁸¹ Bennett.

¹⁸² Bennett.

¹⁸³ Jennifer Walton, Mark Spellman, and Joseph Crabtree, *Evaluation of Thermal Imaging Technology for Commercial Vehicle Screening* (Lexington, KY: University of Kentucky, Kentucky Transportation Center, 2015), 15, <http://dx.doi.org/10.13023/KTC.RR.2015.19>.

¹⁸⁴ Walton, Spellman, and Crabtree, 21.

view.”¹⁸⁵ The ALPR has become a significant asset to law enforcement and public safety agencies, as ALPR cameras can scan and process “up to 1,800 license plates per minute,” which takes human data entry error out of the equation.¹⁸⁶ The ALPR systems compare the captured license plates to connected law enforcement databases and alert police officers of a wanted vehicle. The entire process of capturing, analyzing, and comparing license plate data all occurs within just seconds.¹⁸⁷ The technology has automated a monotonous and disrupting process that officers often complete in their day-to-day operations. It also significantly “improves their efficiency and effectiveness in identifying vehicles of interest among the hundreds of thousands they observe in routine patrol.”¹⁸⁸ Previously, dispatch centers would have to verify stolen vehicle tags upon request of the investigation officer.¹⁸⁹ Now, ALPR systems alert officers automatically when “they are behind a stolen vehicle without having to lift a finger.”¹⁹⁰

ALPR technology has certainly made the patrol officer’s day-to-day tasks easier and more manageable by potentially increasing the number of stolen vehicles recovered and criminals apprehended, but it has also affected officers in other ways as well:¹⁹¹

- The ALPR system serves as a force multiplier for law enforcement officers by allowing them to do more with a limited amount of resources. The ALPR is deployed as an extra set of eyes for law enforcement agencies to help officers be more efficient, but at the same time, limit the amount of unnecessary radio traffic between officers and dispatchers. Officers are thus able to keep focused actively on other potential traffic violations or criminal activity around them while on patrol, as they will not be distracted by calling in license plate information through dispatch

¹⁸⁵ Roufa, “Learn How Today’s Technology Will Transform Tomorrow’s Police.”

¹⁸⁶ Roberts and Casanova, “Automated License Plate Recognition (ALPR) Use by Law Enforcement.”

¹⁸⁷ Roberts and Casanova, 1.

¹⁸⁸ Roberts and Casanova, 10.

¹⁸⁹ Roufa, “Learn How Today’s Technology Will Transform Tomorrow’s Police.”

¹⁹⁰ Roufa.

¹⁹¹ Roberts and Casanova, “Automated License Plate Recognition (ALPR) Use by Law Enforcement,” 1–2.

centers. The police officers become even more effective in deterring and fighting crime.

- The ALPR system provides law enforcement officers with instant on the spot data of a potential wanted or stolen vehicle. This captured data permits a patrol officer to act upon this information quickly and decisively while keeping the safety of the public in mind. The technology allows officers to know what they are dealing with ahead of time before a traffic stop is conducted. This knowledge improves officer safety, because officers will know if they are working with a routine traffic stop or dealing with something more serious in nature.
- The ALPR system provides law enforcement agencies with an additional investigative tool, as it both assists in capturing criminals but in also exonerating the innocent. The ALPR can assist with the investigation of missing children during AMBER alerts or during Silver alerts when vehicles are involved. In addition to mounting the ALPR in a patrol car, it can also be used as a stand-alone system alongside a roadway. A stand-alone ALPR system can possibly be set up to capture all vehicles that pass its location to alert police officers when an AMBER or Silver alert vehicle is in sight. The technology essentially frees up patrol officers instead of dedicating one to sit alongside a roadway looking for the vehicle in question all day long.

ALPR technology has significantly enhanced law enforcement officers' capabilities. It has vastly improved the efficiency of patrol officers and has made their daily tasks much more manageable, all while mitigating their risk while improving safety to the general public. ALPR has not negatively impacted law enforcement officers, but in fact, improved their skillset to allow them to focus their crime fighting skills elsewhere.

D. AIR SAMPLING SENSORS

Air sampling sensors are another technology law enforcement agencies are using. One type of air sampling sensor is called the intracavity laser spectroscopy (ILS), which is a technique used for highly sensitive spectroscopic measurements.¹⁹² The military uses this technology to detect explosives, chemical weapons, or hazardous materials to keep personnel safe in the process.¹⁹³ The lasers are able to detect certain substances in an area or cavity because the energy emitted from the laser is absorbed when a specific substance has been detected. For this detection to occur, a laser must first be set to look at one particular area on the infrared (IR) scale. The overall concept is quite simple. A laser is deployed and retracted back through an area or cavity. Any change in energy upon the laser's return indicates the detection of a substance within this area. This detection can take place up to a kilometer away.

In 2014, researchers at the Military University of Technology in Poland took the technology a step further by designing and testing an ILS sensor to detect alcohol in moving vehicles. The university's goal was to diminish serious vehicle collisions by detecting motor vehicle drivers impaired by alcohol.¹⁹⁴ As a vehicle passes by the ILS sensor, a laser beam is sent through the vehicle's window and bounces off the mirror and returns to the receiver. The laser beam is set at a specific IR wavelength that can be easily absorbed by any alcohol vapor.¹⁹⁵ Since alcohol absorbs the beam and the energy, the lower the power is, the higher the concentration of alcohol in the vehicle. As the "concentration of alcohol in the human blood" goes up, the "transmission of alcohol vapor in the air exhaled by this human being measured by the device" goes down.¹⁹⁶

¹⁹² Valery M. Baev, Torsten J. Latz, and Peter E. Toschek, "Laser Intracavity Absorption Spectroscopy," *Applied Physics B* 69, no. 3 (September 1, 1999): 171–202, <https://doi.org/10.1007/s003400050793>.

¹⁹³ Corinne Iozzio, "Lasers Could Detect Drunk Drivers on the Road," *Smithsonian*, July 1, 2014, <https://www.smithsonianmag.com/innovation/Lasers-Could-Detect-Drunk-Drivers-On-The-Road-180951903/>.

¹⁹⁴ Jarosław Młyńczak, Jan Kubicki, and Krzysztof Kopczyński, "Stand-off Detection of Alcohol in Car Cabins," *Journal of Applied Remote Sensing* 8, no. 1 (May 19, 2014): 083627-4, <https://doi.org/10.1117/1.JRS.8.083627>.

¹⁹⁵ For the 2014 study, a pilot laser was used as a control and the wavelength was set at 3.39 μm .

¹⁹⁶ Młyńczak, Kubicki, and Kopczyński, "Stand-off Detection of Alcohol in Car Cabins," 083627-4.

Based upon the results of the 2014 study, researchers were able to determine accurately the “concentration of alcohol in human blood of at least 0.1%.”¹⁹⁷

ILS alcohol sensors have not yet been deployed but will help law enforcement officers throughout the country by changing the way police officers are able to monitor roadways. While it may take a few more years for the technology to advance enough to be used in conjunction with the APV, it will have an immediate impact on how driving under the influence (DUI) drivers are detected. Police officers can use ILS devices to conduct traffic stops similar to how law enforcement agencies today use LIDAR guns to detect speeders.

LIDAR guns are used regularly by police officers to detect speeders to make a reasonable suspicion traffic stop. LIDAR devices have changed the way officers enforce speeding violations. Before these devices, law enforcement officers would enforce speeding violations by conducting a dangerous bumper pace with the violator’s speeding vehicle. The speed of the police vehicle would have to be matched with that of the violator to obtain reasonable suspicion for a traffic stop. These devices forever changed how speeding violations are enforced, which subsequently makes it safer for the officers. The ILS devices can be used the same way by law enforcement agencies, which ultimately makes the police officers’ job safer in the process. Police officers can either set up an ILS system on the side of the roadway, or it can be used while in a moving police car to target vehicles as they travel through the area. If alcohol is detected in the cabin of a vehicle by the ILS device, a traffic stop can then be conducted to determine if the driver is under the influence.

ILS and LIDAR technology have and will continue to improve the techniques law enforcement officers use in patrolling for DUI drivers. ILS technology can also have an impact on alcohol-related fatalities, as it can potentially save the lives of police officers. From 2008 to 2017, 114 alcohol-related police officer line of duty deaths were

¹⁹⁷ Młyńczak, Kubicki, and Kopczyński, 083627-4.

recorded.¹⁹⁸ Law enforcement agencies nationwide should take every opportunity to reduce these line of duty deaths, and the use of an ILS device is a step in the right direction. This technology is keeping military members safer in the field, and can do the same for police officers, which will forever change how DUI drivers are identified.

E. FACIAL RECOGNITION

Facial recognition uses biometric-based technology, which “is the automated recognition of individuals based on their biological and behavioral characteristics.”¹⁹⁹ The technology can perform a multitude of functions but requires a comparison of a stored and a recent photo. The stored photo of the suspect must already be entered into a known database for facial recognition to work effectively. Once a current photo is captured, facial recognition technology “extracts features from the faces and puts them into a format—often referred to as a faceprint—that can be used for verification.”²⁰⁰ These distinctive face features are then compared to known photos to determine if the two photos are a likely match. This process takes only seconds, and it has reduced the time it takes to identify suspects positively after an arrest.

Perhaps, the most compelling argument for facial recognition technology is that it can make law enforcement agencies more efficient. The technology can assist law enforcement officers monitoring heavily crowded venues or areas to identify criminals if and as they encounter them. Several law enforcement agencies in large metropolitan areas are using facial recognition “on live surveillance camera video” to constantly “scan the faces of pedestrians.”²⁰¹ Additionally, the technology can support law enforcement officers on patrol, such as the Pinellas County Sheriff’s Office (PCSO) in Florida. PCSO is using the technology in a mobile environment and has installed both digital cameras

¹⁹⁸ “Causes of Line of Duty Deaths, Over the Past Decade (2008–2017),” National Law Enforcement Officers Memorial Fund, updated March 15, 2018, <https://nleomf.org/facts-figures/causes-of-law-enforcement-deaths>.

¹⁹⁹ Government Accountability Office, *FACE Recognition Technology: FBI Should Better Ensure Privacy and Accuracy*, GAO-16-267 (Washington, DC: Government Accountability Office, 2016), 5, <https://www.gao.gov/products/GAO-16-267>.

²⁰⁰ Government Accountability Office, 6.

²⁰¹ “The Perpetual Line-Up,” Center on Privacy & Technology at Georgetown Law, October 18, 2016, <https://www.perpetuallineup.org/>.

and docking stations in 50 of its 600 patrol vehicles.²⁰² The deputies use the technology when they stop someone whose identity is in doubt. They take several pictures with the digital camera and then connect it to a mobile docking station to plug in to the County's database of over 850,000 records. The pictures are compared with those stored on file and the computer displays the 24 closest matches. The deputy then makes the decision on site whether the identities match up.²⁰³

Beyond spotting threats in a crowd and being used on patrol, facial recognition systems can be used to support law enforcement agencies in conducting criminal investigations. The New York Department of Motor Vehicles has been using a facial recognition program since 2010 and has identified more than 21,000 possible identity fraud cases.²⁰⁴ The DHS has been experimenting with facial recognition technology to assist in identifying abducted and exploited children.²⁰⁵ The CBP has teamed up with airlines in Boston, Atlanta, Washington, and New York to use facial recognition technology to assist in boarding pass screening.²⁰⁶ Law enforcement agencies are working with schools by installing facial recognition cameras to identify gang members, fired employees, or sex offenders on school grounds.²⁰⁷

Law enforcement agencies are using facial recognition technology to catch violent criminals and fugitives, to prevent school shootings and gang violence on school grounds, to support unsolved criminal cases, and to identify suspects positively during a traffic

²⁰² Jim Weiss, "Facial Recognition Technology in Law Enforcement," Hendon Publishing Company, accessed September 5, 2018, http://www.hendonpub.com/resources/article_archive/results/details?id=4291.

²⁰³ Weiss.

²⁰⁴ "Governor Cuomo Announces Major Facial Recognition Technology Milestone with 21,000 Fraud Cases Investigated," Governor Andrew M. Cuomo, August 21, 2017, <https://www.governor.ny.gov/news/governor-cuomo-announces-major-facial-recognition-technology-milestone-21000-fraud-cases>.

²⁰⁵ "Snapshot: S&T and HSI Collaborate on Technologies to Save Children from Abuse and Exploitation," Department of Homeland Security, March 6, 2018, <https://www.dhs.gov/science-and-technology/news/2018/03/06/snapshot-st-and-hsi-collaborate-technologies-save-children>.

²⁰⁶ Asma Khalid, "Facial Recognition May Boost Airport Security but Raises Privacy Worries," NPR, June 26, 2017, <https://www.npr.org/sections/alltechconsidered/2017/06/26/534131967/facial-recognition-may-boost-airport-security-but-raises-privacy-worries>.

²⁰⁷ Sidney Fussell, "Schools Are Spending Millions on High-Tech Surveillance of Kids," Gizmodo, March 16, 2018, <https://gizmodo.com/schools-are-spending-millions-on-high-tech-surveillance-1823811050>.

stop. This technology, like the others discussed in this section, has impacted police officers by making law enforcement work more efficient while reducing the risk to both the public and the police. It is being used as a force multiplier by reducing or reallocating the law enforcement resources needed by agencies nationwide.

F. GUNSHOT DETECTION SYSTEMS

Gunshot detection systems were developed in the mid-1990s by the Department of Defense with the hope of minimizing gun violence in those cities with high rates of gun incidents.²⁰⁸ The technology can be a very effective way to monitor for gunshots in specific areas, without relying on eyewitness accounts. Throughout the country, most gunshots are unreported, as only about one in six incidents are reported by neighbors.²⁰⁹ Gunshot detection systems use mapping and electronic sensors to triangulate a shooter to allow officers to respond immediately to any gunshots detected by the system. To determine the general location of the gunshot(s) accurately, three sensors must independently detect the acoustic soundwaves produced by the gunfire.²¹⁰ When the soundwave is detected, the system automatically alerts dispatch centers to a location within 25 meters of the actual gunshot(s).²¹¹ Dispatchers are then responsible for deploying and maneuvering patrol officers to the correct location.

The technology is used by more than 90 law enforcement agencies in the United States.²¹² Several of these law enforcement agencies have publicly announced the installation of these systems to “increase a potential shooter’s perceived risks of firing a

²⁰⁸ Lorraine Green Mazerolle et al., “Using Gunshot Detection Systems in Police Departments: The Impact on Police Response Times and Officer Workloads,” *SAGE Journals* 1, no. 2 (June 1, 1998): 21–49, http://journals.sagepub.com/doi/abs/10.1177/109861119800100202?casa_token=MJr-dlwGKz8AAAAA:05_SseJRZkbJHmYr72qU6FPY613O3v_l1oOKAtbz42T93UPiKxZi9zhU-LpPWX0Jymt0AH_N9QLWpA.

²⁰⁹ Tim Prudente and Sarah Meehan, “Baltimore’s New Gunshot Detection System Hears Four Shootings in First Night,” *The Baltimore Sun*, June 1, 2018, <http://www.baltimoresun.com/news/maryland/crime/bs-md-ci-shotspotter-20180601-story.html>.

²¹⁰ Kyung-Shick Choi, Mitch Librett, and Taylor J. Collins, “2014 Gunshot Detection,” Research Gate, July 29, 2016. https://www.researchgate.net/publication/305720016_2014_Gunshot_Detection.

²¹¹ Choi, Librett, and Collins.

²¹² Prudente and Meehan, “Baltimore’s New Gunshot Detection System Hears Four Shootings in First Night.”

weapon.”²¹³ These publicized announcements were meant to deter potential shooters before an incident occurred, with the overarching goal of reducing the crime rate over time. In Camden, New Jersey, and Springfield, Massachusetts, law enforcement agencies have observed a nearly 50% reduction in gunshots since they have implemented a gunshot detection system.²¹⁴

The effectiveness of these systems has been further studied and measured over the last two decades to provide valuable data for law enforcement agencies. A Dallas, Texas study in 1998 looked at the “impact of the technology on officer response times and officer workloads.”²¹⁵ The results of the study are intriguing, as it identified that gunshot detection systems reduced officer response times by 7%; however, it greatly increased officers’ workload.²¹⁶ While the technology decreased response times to crimes in progress, it also decreased overall officer efficiency, which thus made their jobs more difficult. This study ultimately indicated that gunshot detection systems had the inverse effect on the role of the police officer when compared to other technologies discussed in this section.

A 2014 study conducted in Brockton, Massachusetts expanded the focus of the 1998 study to include “dispatch times and case outcomes.”²¹⁷ The findings of the study determined that gunshot detection systems improved police effectiveness in both dispatch response times (time it takes to dispatch a call) and officer response times (time it takes for the officer to respond).²¹⁸ However, the study also found that the technology was not that effective in achieving higher desired cases outcomes. In other words, gunshot detection systems are effective in getting police on scene quicker, but do not assist in solving the criminal cases.

²¹³ Choi, Librett, and Collins, “2014 Gunshot Detection.”

²¹⁴ Prudente and Meehan, “Baltimore’s New Gunshot Detection System Hears Four Shootings in First Night.”

²¹⁵ Mazerolle et al., “Using Gunshot Detection Systems in Police Departments.”

²¹⁶ Mazerolle et al.

²¹⁷ Choi, Librett, and Collins, “2014 Gunshot Detection.”

²¹⁸ Choi, Librett, and Collins.

While the technology for gunshot detections systems has been available for several years, the 2017 mass shooting in Las Vegas, coupled with several recent nationwide school shootings, has prompted law enforcement agencies to become even more innovative with gunshot detection systems. Emerging gunshot detection systems are being tested by law enforcement agencies in a mobile environment and in school districts to alert authorities when gunshots are fired.²¹⁹ These systems, currently being tested at Hermosa Elementary School in Artesia, New Mexico, will also lock classroom doors when gunshots are detected.²²⁰ The technology allows teachers and administrators to focus on moving children to safe areas instead of trying to secure classrooms while attempting to call 911. This system not only assists law enforcement officers by keeping children safe during a school shooting, but also helps alleviate fears in the community.

G. THROUGH-THE-WALL SENSORS

TTWS technology can detect any type of motion through an interior or exterior brick, concrete, wood, plaster, or fiberglass wall²²¹ These sensors can currently only be used in a standoff environment but do not have to be placed directly against a wall to function.²²² Law enforcement agencies can utilize this technology to increase situational awareness during rescue operations and other tactical scenarios. Officers could also benefit from this technology by being able “to detect individuals to more quickly clear dangerous areas (e.g., buildings that are on fire could be more quickly checked for trapped survivors)” or “to more easily locate survivors after a building collapse.”²²³

At least 50 law enforcement agencies have been utilizing this technology since 2012, but the Federal Bureau of Investigation (FBI) and the U.S. Marshals Service have garnered the most attention for its use. While law enforcement industry best practices

²¹⁹ Lulu Chang, “New Sensor System Detects Gunshots, Can Automatically Lock down a School,” Digital Trends, April 3, 2018, <https://www.digitaltrends.com/cool-tech/sensor-detects-gunshots/>.

²²⁰ Chang.

²²¹ “Through-the-Wall Surveillance,” National Institute of Justice, last modified January 23, 2015, <https://www.nij.gov:443/topics/technology/detection-surveillance/enhanced-surveillance/pages/through-wall.aspx>.

²²² National Institute of Justice.

²²³ Ericson et al., “Through-the-Wall Sensors (TTWS) for Law Enforcement, 1.

recommend that agencies acquire a search warrant before using TTWS, case law has not been established for how TTWS should be deployed.²²⁴ A 2014 ruling by the 10th Circuit Court of Appeals was the first to reference the technology when it upheld a search by the U.S. Marshals using TTWS technology.²²⁵ Civil liberty advocates have raised constitutional concerns about the legality of TTWS technology, as more court cases are likely to occur with its continued use.

This technology certainly benefits law enforcement officers by mitigating their safety concerns while assisting them in catching wanted criminals. As the technology continues to evolve, it can also be beneficial for law enforcement agencies to utilize TTWS in a mobile environment, such as use on an APV.

H. CHAPTER SUMMARY

The APV platform is designed with standard AV technology but is also packaged with complementary technologies including the UAS, facial recognition, thermal imaging, ALPR, air sampling devices, and gunshot detection systems. Existing wireless sensor networks are already beneficial to law enforcement agencies as stand-alone systems. However, when combined in a complex platform, such as the APV, current research suggests that the APV may immediately be a force multiplier for law enforcement agencies and its officers.

The next chapter discusses how the APV can be used as a force multiplier and benefit law enforcement agencies. Additionally, the chapter evaluates potential concerns, such as privacy and legal implications.

²²⁴ Jon Hayes and Lars Ericson, “Through-the-Wall Sensors for Law Enforcement: Best Practices,” Google, March 2014, <https://www.google.com/search?client=safari&rls=en&q=Through-the-Wall+Sensors+for+Law+Enforcement:+Best+Practices&ie=UTF-8&oe=UTF-8>.

²²⁵ United States v. Denson, No. 13-3329 (10th Cir. 2014), <https://law.justia.com/cases/federal/appellate-courts/ca10/13-3329/13-3329-2014-12-30.html>.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. AUTONOMOUS POLICE VEHICLE CONSIDERATIONS

Based upon the research on AV technology, UAS and wireless sensor networks technologies, and the author's law enforcement experience, benefits and concerns can be extrapolated and applied to the entire APV platform. This chapter explores and discusses those potential benefits and concerns in great depth.

A. APV BENEFITS

Imagine an APV patrolling U.S. roadways in an autonomous world, scanning every vehicle's license plate, recognizing every driver and passenger, and identifying any illegal substances or devices within those vehicles. The opportunities presented to law enforcement agencies would be endless. The APV could be involved in safe pursuits of criminals or vehicles, conduct surveillance, or help set up a perimeter. Additionally, they could scan for chemical, nuclear, biological, or radioactive substances while mitigating the risk to its officers.

APVs would not only be instrumental to law enforcement agencies nationwide, but the platform would be essential to the entire homeland security enterprise. Similar to how fire departments transformed into all-hazard response organizations, the APV could be used as an "all-hazards response vehicle." The APV could patrol U.S. roadways and borders to reduce the vulnerability of the United States to terrorism as easily as it could respond to natural disasters to locate survivors. The APV could also be used at pandemic or nuclear fallout scenes to help identify those affected by the disasters. Based on the research, the APV seems essential for the future to both law enforcement agencies and the larger homeland security enterprise.

The APV can be used by law enforcement agencies in either a staffed or an unstaffed configuration. In both configurations, the APV is fully autonomous, yet the staffed APV will allow a police officer to take control of the vehicle if necessary. Law enforcement agencies are much more comfortable adopting established technologies

rather than emerging technologies.²²⁶ Considering this trend, it is not inconceivable to imagine law enforcement agencies initially adopting staffed APV units, which is similar to how both the military and law enforcement have adopted the UAS platform. Fully autonomous UAS flight is only now beginning to be considered in law enforcement agencies after several years of being remotely piloted. A staffed APV initially will allow law enforcement agencies to become comfortable with the emerging technology before considering unstaffed APV units. The following benefits and concerns of APV implementation mostly revolve around staffed APV units; however, unstaffed APV units are briefly touched upon in certain scenarios.

1. Efficiency

What happens when law enforcement officers have everything they need in their police vehicles or on their person and they do not have the responsibility of driving? What happens when their police vehicle becomes part of the larger IoT technology package and they can instantly access reports, databases, and sensor data? They are safer, more efficient, less prone to error, and have even more ability to protect law-abiding citizens from those who elect to break the law.

Today's police officer's role has been centered on multi-tasking as much as possible to be successful. The police officer must focus on driving, listening to the radio for calls, monitoring traffic, and utilizing keyboard-driven, in-car systems, such as the mobile digital terminal (MDT). Police officers must do all of this while also constantly monitoring their surroundings for criminal activity or traffic infractions. These multiple distractions do not allow the police officers to be the most efficient during the course of their work. In fact, these multiple distractions may have led to an increase in patrol vehicle collisions and line of duty deaths.

A five-year study (2010–2014) by the National Law Enforcement Officers Memorial Fund determined that nearly 40% of officers died in the line of duty from being

²²⁶ Kevin J. Strom, *Research on the Impact of Technology on Policing Strategy in the 21st Century: Final Report* (Rockville, MD: Office of Justice Programs' National Criminal Justice Reference Service, 2016), 7–8.

in an automobile crash or being struck by an automobile.²²⁷ The report also found “a large number of the crashes investigated were not related to either a call for service or a case of self-initiated activity.”²²⁸ This report is telling, which suggests that many line of duty deaths can be attributed to the officers being distracted while driving. Many of these deaths could have been avoided if the APV had been utilized.

Based upon AV, UAS and wireless sensor technologies research, it can be surmised that the APV may improve working conditions and efficiency for law enforcement officers. Thus, it is the author’s opinion that the APV will improve working conditions and efficiency in the following ways:

- Increased responsiveness—The APV would be connected to dispatch centers and would be programmed to respond automatically to calls for service. The APV would utilize the built-in navigation systems on board to calculate the most direct and efficient response to the call. Thus, the guess work out is taken out of the equation for the patrol officers when determining the best route, and therefore, the response would be quicker and more efficient. Consequently, the police officers are then able to focus on other duties instead of having to concentrate on driving through traffic.
- Better data-based decision making—The APV would have access to police databases, facial recognition, thermal imagers, air sampling, ALPRs, and other advanced sensors while patrolling. The APV would be simultaneously scanning for criminal activity while driving. These scanners would alert the patrol officers of any criminal activity in the general vicinity of the APV. Essentially, the APV becomes the trusted partner of the police officers and uses data driven technology to assist the patrol officers in their decision making.

²²⁷ Nick Breul and Mike Keith, *Deadly Calls and Fatal Encounters: Analysis of U.S. Law Enforcement Line of Duty Deaths When Officers Responded to Dispatched Calls for Service and Conducted Enforcement (2010–2014)* (Washington, DC: Department of Justice, 2015), 12, <https://www.hsd1.org/?abstract&did=794863>.

²²⁸ Breul and Keith, 12.

- More accountability and increased transparency in policing—The APV would be equipped with tracking devices, recording devices, and cameras to capture the police officers' every public contact. In an era of increased transparency between law enforcement agencies and the community, this transparency would be crucial to obtaining and keeping the public's trust. The APV platform would ensure the oversight mechanisms would be in place for accountability purposes.
- Better morale for officers—The APV would allow police officers to improve on the job performance. Police officers would be able to leverage APV technology to augment their own experience, talents, and intuition. The APV would improve officer moral by helping them make better decisions and better use of their time.

The APV permits the police officers to be more efficient in their everyday tasks and spend more time on secondary tasks. The APV platform would give police officers the necessary tools they need to make smarter, quicker, safer, and more productive decisions. It ultimately frees them up to do an important, necessary, and difficult job without being constantly distracted.

2. Officer Safety

The APV may improve officer safety in several ways when on patrol. The most obvious situations are during a traffic stop and during a high-speed pursuit. When officers are on patrol and making a traffic stop, safety is the primary consideration. The officers are at a complete disadvantage with several unknowns associated with the stopped vehicle. The officers do not know who or what is in the stopped vehicle. The officers can possibly be stopping a murderer, robber, drug smuggler, sexual predator, or another potentially violent criminal.

The APV would be equipped with advanced sensor technology and would be able to assist with identifying traffic violations and criminal activity to establish reasonable

suspicion for a traffic stop. The APV would also be able to assist the police officer in identifying the occupants and any contraband in the stopped vehicle.

With a thermal imager, the APV can scan the vehicle at a distance to identify all the occupants in the vehicle. With an APLR, the APV can run the license plates of the vehicle to identify if it is stolen. With facial recognition, the APV can scan all the occupants of the vehicle to obtain any potential criminal histories or warrants. The APV gathers all this information quickly for the police officer and provides information about what to expect from the driver or occupants of the vehicle. The more information an officer has prior to making contact, the greater the chance of the officer mitigating the safety risks.

Another critical way the APV can safely assist an officer during a traffic stop is identifying the transport of illegal drugs. The Department of Justice (DOJ) reported that from January through November 2009, the seizure of illegal drugs in transit exceeded 1,626 metric tons.²²⁹ While Mexican drug trafficking organizations (DTOs) use different drug trafficking techniques, overland vehicles transport over 97% of the illegal drugs seized in the United States.²³⁰ The vast majority of illegal drugs smuggled overland into the United States come from Mexico, with a smaller percentage being smuggled in from Canada.²³¹ DTOs have dominated the transportation of illegal drugs and have primarily used “commercial trucks and private and rental vehicles” to traffic the drugs across the Mexican border.²³² As more illegal drugs have been seized by law enforcement, DTOs have become even more creative in their smuggling techniques. In October 2016, CBP agents discovered 88 pounds of methamphetamines inside a commercial vehicle camouflaged by a consignment of carrots.²³³ In another incident, law enforcement

²²⁹ “Drug Movement into and within the United States,” Department of Justice, February 2010, <https://www.justice.gov/archive/ndic/pubs38/38661/movement.htm#Flow>.

²³⁰ Department of Justice.

²³¹ Department of Justice.

²³² Department of Justice.

²³³ Christopher Woody, “Fake Vegetables, Frozen Sharks, and an Xbox—Here Are Some of Drugs Smugglers’ Most Bizarre Methods,” Business Insider, April 2, 2017, <http://www.businessinsider.com/drug-smugglers-methods-hiding-places-2017-4>.

officers in Chicago confiscated over 50 kilos of cocaine disguised as a shipment of tomatoes.²³⁴ These examples are just a sampling of how DTOs have resourcefully adapted to law enforcement intervention, but what these stories have in common is that the illegal drugs are being smuggled overland via a vehicle.

DTOs have been creative with their vehicles as well. The Drug Enforcement Administration (DEA) led a 22-month investigation in 2010 known as “Project Deliverance,” which resulted in the seizure of \$154 million and 2,266 arrests.²³⁵ During this investigation, DEA agents were surprised by the ingenuity DTOs demonstrated when they found illegal drugs in an array of hidden compartments inside vehicles.²³⁶ Agents found hidden compartments using magnetic locks and hidden switches, as well as stuffed dead spaces created in the design of the vehicle.²³⁷ They also found illegal drugs “in airbag compartments, inside false gas tanks, in spaces under seats, and inside tires.”²³⁸ The APV would be able to identify any illegal drugs hidden in false compartments or otherwise, and ultimately reduce the police officers’ risk of being caught off guard during a traffic stop.

It is widely assumed that AVs will be safer than human drivers because AVs will be equipped to monitor driving conditions continually on the roadways that will result in fewer traffic collisions.²³⁹ Thus, maybe the most beneficial way an APV can improve officer safety is by reducing the number of traffic related police officer collisions and fatalities. Although it is infrequently reported, police pursuits and traffic collisions kill roughly as many officers as do firearms.²⁴⁰ The most recent annual report from the FBI’s

²³⁴ Woody.

²³⁵ Staff Writer, “DEA-Led Operation Delivers More Than 2,000 Arrests,” *POLICE Magazine*, June 10, 2010, <http://www.policemag.com/channel/gangs/news/2010/06/10/dea-led-operation-delivers-over-2-000-arrests.aspx>.

²³⁶ Paul Clinton, “Hidden Drugs in Vehicle ‘Traps,’” *POLICE Magazine*, July 6, 2010, <http://www.policemag.com/channel/gangs/articles/2010/07/hiding-drugs-in-vehicle-traps.aspx>.

²³⁷ Clinton.

²³⁸ Clinton.

²³⁹ Thompson, “Why Driverless Cars Will Be Safer than Human Drivers.”

²⁴⁰ “Honoring Officers Killed in 2018,” Officer Down Memorial Page, 2018, <https://www.odmp.org/search/year/2018>.

Crime Reporting program indicates that 1,068 officers have been killed in the line of duty.²⁴¹ This number is staggering, as over 100 officers are killed in the line of duty each year. However, it is even more striking when breaking this down even further, as 577 officers died in collisions, almost all involving a motor vehicle.²⁴² In over 70% of those accidents, the officer was driving the vehicle when the fatal collision occurred.²⁴³

Whether the officers were distracted while driving or driving beyond their capability, the human factor plays a role each time a collision occurs. Recent statistics from NHTSA indicated that more than 90% of vehicle collisions in the United States are the result of driver error.²⁴⁴ Police officers drive endless miles a year; thus, their exposure to traffic puts them in harm's way each and every day. To comprehend how the APV might mitigate the risk to officers, it is only necessary to look no further than police pursuits. In 2012, "state and local enforcement agencies conducted an estimated 68,000 vehicle pursuits."²⁴⁵ This number equates to over 186 pursuits per day nationwide. Police pursuits are precarious, often times involving reckless driving that endangers both the police and public. From 1996 to 2015, an average of 355 people were killed each year in pursuit-related accidents.²⁴⁶

The APV on patrol could reduce this number substantially. Ideally, the APV would identify the driver and occupants utilizing its sensor networks. Once this information would be captured, the police would not have to continue the pursuit, as they would be able to locate and arrest the driver later. If identification were not possible, the APV could be programmed to pursue the suspect at a safe speed. The APV takes the human error out of the equation. Thus, the APV in pursuit of a suspect would be safer

²⁴¹ "Uniform Crime Reporting (UCR) Program," Federal Bureau of Investigation, accessed June 5, 2018, <https://www.fbi.gov/services/cjis/ucr>.

²⁴² Federal Bureau of Investigation.

²⁴³ Federal Bureau of Investigation.

²⁴⁴ "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey," Transportation Research Board, accessed October 13, 2018, <http://www.trb.org/Main/Blurbs/172209.aspx>.

²⁴⁵ Brian A. Reaves, "Police Vehicle Pursuits, 2012–2013," Bureau of Justice Statistics, May 9, 2017, <https://www.bjs.gov/index.cfm?ty=pbdetail&iid=5906>.

²⁴⁶ Reaves.

and less risky for law enforcement agencies. Ultimately, the APV would alleviate the risk to officers during all traffic stops and traffic related incidents.

3. Improving Fugitive Searches and Search and Rescue Operations

The APV could be used in fugitive searches or search and rescue missions similar to how law enforcement agencies have used the UAS. The APV equipped with thermal imagers provide law enforcement officers an alternate solution to locating a hidden suspect. Dark or camouflaged suspects are difficult to locate by the naked eye or flashlights and put the officers at a disadvantage. With the APV, the officers would have the ability to detect a suspect's body no matter if they were hiding inside a structure or outdoors. Connected APVs could utilize its entire sensor network and coordinate search efforts in wooded locations, open fields, or even near lakes, rivers, or streams.²⁴⁷ The APV would detect any suspect or victim's ambient heat in these locations, as long as they were not "completely submerged" in open water.²⁴⁸

In many locations, the fire department usually takes the lead when conducting search and rescue operations for missing persons. In a connected environment, the APV would be able to tap into the fire department's networks to conduct coordinated public safety searches to minimize a duplication of efforts and allow a more efficient operation. With a thermal imager, the APV would "be able to search up to 1,500 feet in any direction," by allowing the APV to assist public safety personnel in searching the most difficult terrain features and locate missing persons in the shortest amount of time possible.²⁴⁹

The APV could also be equipped with an attached UAS. The APV could deploy the UAS in locations where an APV would be unable to travel to gain an overhead perspective of the area. The UAS would be constantly communicating with the APV of locations searched to provide for a thorough and effective ground and air search. This

²⁴⁷ Brad Harvey, "Top 10 Uses for Thermal Imaging in Law Enforcement," *Tactical Response Magazine*, 3, June 2006, <https://www.bullard.com/press-release/11/top-10-uses-for-thermal-imaging-in-law-enforcement>.

²⁴⁸ Harvey, 10.

²⁴⁹ Harvey, 10.

information could be sent to all other APVs in the area; again, to maximize the efficiency of the search. The advantages the APV provides in these search and rescue missions are endless, as they serve as a force multiplier for the entire operation.

4. Community Policing

Community policing and “walking the beat” used to be the model of ideal policing. Police would interact with the community and built trusting relationships with its members. The last attempt to foster a community-police partnership was in 1994, when President Bill Clinton was in office and signed the “Violent Crime Control and Law Enforcement Act (P.L. 103-322).”²⁵⁰ This act cost \$7.5 billion and established the Office of Community Oriented Policing Services (COPS).²⁵¹ The objective of this program was to add “100,000 additional police officers” in high crime areas with the intent of improving community-police relationships.²⁵² However, according to the Government Accountability Office, the program was ineffective and contributed to only a “1.3 percent decline in the overall crime rate.”²⁵³ During the recession, many of the community policing programs had to be cut due to shrinking budgets and lack of tangible results.²⁵⁴ Several types of policing models have been competing for attention since, such as “procedural justice policing, predictive policing, intelligence oriented policing, hot spots policing, and metrics-driven policing.”²⁵⁵ The civil unrest in Ferguson, Missouri and other places around the country are a reminder that law enforcement agencies need to engage in community policing.

²⁵⁰ Ralph Rector, “The Facts about COPS: A Performance Overview of the Community Oriented Policing Services Program,” The Heritage Foundation, September 25, 2000, <https://www.heritage.org/crime-and-justice/report/the-facts-about-cops-performance-overview-the-community-oriented-policing>.

²⁵¹ Rector.

²⁵² Rector.

²⁵³ Government Accountability Office, *Community Policing Grants: COPS Grants Were a Modest Contributor to Declines in Crime in the 1990s*, GAO-06-104 (Washington, DC: Government Accountability Office, 2005), 1, <https://www.gao.gov/products/GAO-06-104>.

²⁵⁴ Wesley Skogan, *What Happened to Community Policing?* (Washington, DC: Community Oriented Policing Services, n.d.), 1, accessed June 18, 2018, https://cops.usdoj.gov/pdf/taskforce/submissions/Skogan_Wesley_Testimony.pdf.

²⁵⁵ Skogan, 2.

Community policing is essential to public safety on both the local and national levels and has a significant role to play in homeland security. In September 2015, a forum on “Building Interdisciplinary Partnerships to Prevent Violent Extremism” was held with community leaders and law enforcement executives in Minneapolis, Minnesota.²⁵⁶ The goal of the forum was to build successful community-police partnerships by allowing forum members to discuss new ideas on how to “prevent violent extremism.”²⁵⁷ The forum presented four cases studies in major metropolitan areas where police departments were “empowering their communities to be resistant to extreme ideologies by building strong relationships with its members, keeping communication channels open, and providing access to services and resources that support prevention and intervention.”²⁵⁸ The lessons learned from this forum suggested that a community-policing program is necessary for law enforcement agencies to engage violent extremism on the front lines.

The APV could assist communities with the “Walk n’ Roll police patrol concept.”²⁵⁹ The concept combines the benefits of foot patrol with the efficiency advantages of the APV.²⁶⁰ Foot patrol officers would be escorted by their APV through neighborhoods at walking speeds. If traffic or the streets did not permit the APV to accompany the patrol officers, it could park on a block being patrolled by the officers and then drive to the next block as the officers advance.²⁶¹ The officers would be able to communicate with the APV throughout the assignment and summon the vehicle at any time. The APV would serve as the partner officers and be able to perform the following functions:²⁶²

- Provide transport for the officer, victims or suspects.

²⁵⁶ Police Executive Research Forum, *Building Interdisciplinary Partnerships to Prevent Violent Extremism* (Washington, DC: Office of Community Oriented Policing Services, 2017), 2.

²⁵⁷ Police Executive Research Forum, 2.

²⁵⁸ Police Executive Research Forum, 12.

²⁵⁹ Finkelstein and Davis, *Autonomous Cars for Law Enforcement*, 8.

²⁶⁰ Finkelstein and Davis, 8.

²⁶¹ Finkelstein and Davis, 10.

²⁶² Finkelstein and Davis, 10.

- Perform consistent 360-degree surveillance for situational awareness while the officers are walking foot patrol.
- Communicate with both the officers and dispatch centers and report suspicious activities.
- Communicate directly with the public in several languages to improve public trust.
- Maintain daily records for the officers on all contacts and unusual observations, analyze the records, and provide a daily summary report.
- Allow foot patrols in remote locations to improve community trust.
- Serve as a mobile police station to allow the community to interact with law enforcement to report neighborhood crimes.

Law enforcement agencies would be able to make a firm commitment to community policing programs by utilizing the APV in this capacity. The APV teamed with the foot patrol officers combines the best of both worlds and would provide the ultimate community-centered policing.

5. Support and Coordination with Fire and EMS and Other Government Agencies

As discussed earlier in this chapter, AV technology will not just impact law enforcement agencies, but all public safety organizations. Current research is being conducted on the feasibility of an autonomous fire truck.²⁶³ Autonomous emergency medical service (EMS) vehicles have also been recently discussed.²⁶⁴ In the foreseeable future, it will only be a matter of time before additional public safety vehicles will be operated autonomously.

²⁶³ Wesley D. Chestnut, "Fire Truck of the Future," Fire Apparatus Manufacturers' Association, April 4, 2017, <https://www.fireapparatusmagazine.com/articles/print/volume-22/issue-4/departments/fama-forum/fire-truck-of-the-future.html>.

²⁶⁴ ECI, "The Ambulance of the Future," *Homeland Security* (blog), October 2, 2017, <https://medium.com/homeland-security/the-ambulance-of-the-future-264bb32c9e6e>.

The APV would be able to communicate efficiently with all other public safety vehicles when responding to a call. The connected vehicles would be able to determine which agency is on scene first and the location of each of their resources. Responding police officers would not have to communicate through dispatch, which thus eliminates potentially inaccurate information. Once all the connected vehicles were on scene, the APV could be directed to close down specific roads or be called upon to assist in a rescue operation.

Incident command concerns would ultimately be eliminated for the police officers. The first connected vehicle on scene would act as the incident command vehicle, determine what kind of incident is involved (criminal, fire, hazmat, EMS, etc.), and coordinate locations of perimeter security, hot zones, safety zones, and do not enter zones. In a traditional incident command situation, the first public safety official on scene would have to map these areas out by hand and coordinate through multiple dispatch centers. The APV would become part of the connected vehicle public safety group, which ultimately would eliminate much of the work for the police officers.

B. APV CONCERNS

While the APV potentially presents obvious benefits to law enforcement agencies and its officers, it would also be subject to criticism and concerns. The following concerns would need to be addressed prior to implementation by law enforcement agencies.

1. Weaponization

a. Kinetic (Bombs and Vehicle Borne Improvised Explosive Devices)

Since 2006, at least 34 incidents have occurred in which drivers have used their vehicles as weapons that resulted in the deaths of 194 people and at least 1,046 others injured.²⁶⁵ The number of attacks has steadily increased each year, as eight documented

²⁶⁵ “Vehicles as Weapons of Terror,” Counter Extremism Project, May 22, 2017, <https://www.counterextremism.com/vehicles-as-weapons-of-terror>.

incidents happened in 2017.²⁶⁶ October 31, 2017 marked the first time this type of attack had occurred on U.S. soil “when Sayfullo Saipov killed eight people in New York...by driving a truck through a bicycle path.”²⁶⁷ Saipov has been charged with federal terrorism and providing “material support” to the Islamic State of Iraq and Syria (ISIS).²⁶⁸ Terrorist organizations, such as Hamas, al-Qaeda, and ISIS, have been calling for and claiming vehicle attacks in recent years.²⁶⁹ In al-Qaeda’s second edition of *Inspire* magazine, editor-in-chief Yahya Ibrahim wrote an article calling for vehicle attacks.²⁷⁰ Ibrahim suggested using a four-wheel drive pickup truck to take out the enemies of Allah.²⁷¹ Ibrahim continues, saying that the “ideal location is a place where there are maximum number of pedestrians and the least number of vehicles.”²⁷² He further asserts this type of attack “could be implemented in the countries like Israel, the U.S., Britain, Canada, Australia, France, Germany, Denmark, Holland, and other countries...” but the attack must “be considered a martyrdom operation.”²⁷³

Terrorist organizations could capitalize on APV technology by using these vehicles as lethal weapons without having to utilize volunteers to conduct a martyrdom operation. Thus, a greater number of future incidents potentially could result, as a driver would not be physically needed to carry out these attacks. In a recent report by the Strategic Issues Group within the FBI, one of the overriding concerns involving the AV is that terrorists may be able to program these vehicles to become vehicle borne

²⁶⁶ Associated Press, “A Look at Attacks Where Vehicles Have Been Used as Weapons,” *Chicago Tribune*, October 31, 2017, <http://www.chicagotribune.com/news/nationworld/ct-vehicles-as-weapons-20171031-story.html>.

²⁶⁷ Jessica Wolfendale, “The Moral Questions in the Debate on What Constitutes Terrorism,” *The Conversation*, December 11, 2017, <http://theconversation.com/the-moral-questions-in-the-debate-on-what-constitutes-terrorism-86990>.

²⁶⁸ Nicole Chavez et al., “New York Attack: Suspect Charged with Terrorism Offenses,” CNN, November 1, 2017, <http://www.cnn.com/2017/11/01/us/new-york-attack/index.html>.

²⁶⁹ Counter Extremism Project, “Vehicles as Weapons of Terror.”

²⁷⁰ Yahya Ibrahim, “The Ultimate Mowing Machine,” *Inspire Magazine* 2 (2010): 53–54.

²⁷¹ Ibrahim, 53.

²⁷² Ibrahim, 53.

²⁷³ Ibrahim, 54.

improvised explosive devices (VBIED).²⁷⁴ As the number of vehicle attacks continues to increase, cause for concern is created for law enforcement agencies because these attacks become difficult to stop. With the advent of the AV, it becomes even more challenging for law enforcement agencies as they leverage this technology.

b. Cyberattacks

On May 12, 2017, the WannaCry ransomware spread around the world and took out thousands of targets, to include public utilities and major corporations.²⁷⁵ The WannaCry ransomware eventually collected over \$130,000 in just a few minutes before it was shut down.²⁷⁶ In September 2016, Yahoo announced it had been the victim of the biggest data breach in history where over 500 million users' information had been compromised.²⁷⁷ This breach equated to an estimated loss of approximately \$350 million for Yahoo.²⁷⁸ In September 2017, the DHS confirmed that Russian government hackers interfered with the 2016 presidential election in 21 states.²⁷⁹ This cyberattack during the presidential election included, "incursions into voter database and software systems," in an attempt to delete or alter data.²⁸⁰

Cyberattacks have become more common over the last several years. In 2005, 67% of 7,818 businesses surveyed detected at least one cybercrime, but only 11%

²⁷⁴ Mark Harris, "FBI Warns Driverless Cars Could Be Used as 'Lethal Weapons,'" *The Guardian*, July 16, 2014, sec. Technology, <http://www.theguardian.com/technology/2014/jul/16/google-fbi-driverless-cars-lethal-weapons-autonomous>.

²⁷⁵ Lily Hay Newman, "The Biggest Cybersecurity Disasters of 2017 So Far," WIRED, July 1, 2017, <https://www.wired.com/story/2017-biggest-hacks-so-far/>.

²⁷⁶ Newman.

²⁷⁷ Taylor Armerding, "The 16 Biggest Data Breaches of the 21st Century," CSO Online, 16, October 11, 2017, <https://www.csoonline.com/article/2130877/data-breach/the-16-biggest-data-breaches-of-the-21st-century.html>.

²⁷⁸ Armerding.

²⁷⁹ Sari Horwitz, Ellen Nakashima, and Matea Gold, "DHS Tells States about Russian Hacking during 2016 Election," *Washington Post*, September 22, 2017, https://www.washingtonpost.com/world/national-security/dhs-tells-states-about-russian-hacking-during-2016-election/2017/09/22/fd263a2c-9fe2-11e7-8ea1-ed975285475e_story.html?utm_term=.fe551a19fb9b.

²⁸⁰ Michael Riley and Jordan Roberston, "Russian Cyber Hacks on U.S. Electoral System Far Wider than Previously Known," Bloomberg, June 13, 2017, <https://www.bloomberg.com/news/articles/2017-06-13/russian-breach-of-39-states-threatens-future-u-s-elections>.

detected a cybertheft.²⁸¹ Since January 2005, almost 1,013,000,000 records containing sensitive personal information was compromised during cyberattacks.²⁸² By 2021, cyberattacks are estimated to exceed \$6 trillion in damages, which suggests that in the next four years, “cybercrime might become the greatest threat to every person, place and thing in the world.”²⁸³

The APV will be the repository for large amounts of data, as these vehicles will be programmed to share and collect information from other connected vehicles and smart cities. Any connected device has the potential to be compromised by the criminal deviant. The APV provides ample opportunities for cyberattacks. A criminal mastermind fluent in cybercrime could have the ability to commandeer a fleet of APVs and create mass chaos in a major city by using them as weapons. Criminals could compromise the APV and steal all its sensitive personal data. However, whether the criminal actor is obtaining sensitive personal information or attempting to overtake the controls of an APV, law enforcement agencies must be prepared to react and mitigate this new threat.

2. Kill Switch Technologies

Waymo, an autonomous car development company, is actively working with the Chandler Police Department in Arizona to test and develop technologies that will assist law enforcement agencies in the near future.²⁸⁴ The partnership hopes to assist first responders in determining how to handle AVs during traffic stops, collisions, and emergency responses. The technology being reviewed during these types of incidents is a “kill switch” that would give law enforcement agencies the ability to shut down an AV if needed.²⁸⁵ The kill switch would override the artificial intelligence in the AV to give law

²⁸¹ “Cybercrime,” Bureau of Justice Statistics, last revised February 1, 2019, <https://www.bjs.gov/index.cfm?ty=tp&tid=41>.

²⁸² Anonymous, “Threat Stats,” *SC Magazine; New York* 26, no. 3 (March 2015): 8–9.

²⁸³ Steve Morgan, “Top 5 Cybersecurity Facts, Figures and Statistics for 2017,” CSO Online, October 19, 2017, <https://www.csoonline.com/article/3153707/security/top-5-cybersecurity-facts-figures-and-statistics-for-2017.html>.

²⁸⁴ Linda Poon, “How Police Are Preparing for the Arrival of Autonomous Cars,” City Lab, October 25, 2017, <https://www.citylab.com/transportation/2017/10/waymo-police-first-responders-emergency-vehicles-driverless-cars/543351/>.

²⁸⁵ Poon.

enforcement agencies the ability not only to turn off an AV during a collision or traffic stop, but also during a criminal activity, such as a high-speed pursuit. A type of kill or overriding switch would also give police officers the ability to override an AV during an emergency response by first responders that safely moves an AV out of the way of police vehicles, fire trucks, or ambulances. In addition, a kill or overriding switch could stop a drug trafficker, vehicle attack, or the potential takeover of an AV by a cyberattacker. Kill switch technologies should also be considered to shut down an APV to mitigate the vehicle from being used as a weapon.

A kill switch comes with concerns as to its use and potential abuse. Could a kill switch be hacked by a nefarious actor? Would law enforcement officers abuse their powers by having access to a master kill switch? These concerns are valid as technology companies are coping with this today. In 2015, California Senate Bill 962 became law, which requires all smartphones sold in California to have an opt-out “kill-switch.”²⁸⁶ If a smartphone is lost or stolen, the owner has the ability to deactivate the phones remotely, which essentially renders them useless.²⁸⁷ The law also provides law enforcement agencies with the authority to use the feature to disable smartphones, which raises concerns about abuse by civil liberties groups.²⁸⁸ Any feature accessible to consumers and law enforcement could be accessible by cyberhackers as well. The kill switch law has so far been successful, as smartphone thefts immediately dropped 32% after the law went into effect.²⁸⁹ A recent study in San Francisco reveals that smartphone thefts are down 50% since 2013, which indicates that thefts of smartphones continue to plummet.²⁹⁰ Thus far, the kill switch has proven to be very effective, as this law may pave the way for future

²⁸⁶ “SB 962, Senate Bill—Introduced by Senator Leno,” California Legislative Information, accessed November 16, 2017, http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_0951-1000/sb_962_bill_20140206_introduced.htm.

²⁸⁷ California Legislative Information.

²⁸⁸ Matt Jeacock, “How Cops and Hackers Could Abuse California’s New Phone Kill-Switch Law,” WIRED, August 26, 2014, <https://www.wired.com/2014/08/how-cops-and-hackers-could-abuse-californias-new-phone-kill-switch-law/>.

²⁸⁹ Ellen Huet, “As California Kill-Switch Law Takes Effect, Smartphone Theft Already Down 32%,” *Forbes*, July 1, 2015, <https://www.forbes.com/sites/ellenhuet/2015/07/01/as-california-kill-switch-laws-takes-effect-smartphone-theft-already-down-32/>.

²⁹⁰ Amy Hollyfield, “Smartphone Theft down in San Francisco,” ABC7 San Francisco, July 28, 2017, <http://abc7news.com/2257099/>.

AV technology and should be monitored closely by law enforcement and lawmakers. While the development of this technology may cause some concerns going forward, a kill switch seems to be a necessity for vehicles in the future AV world.

The kill switch in addition to other enhanced “kill” technologies should be a priority for law enforcement agencies to research going forward. These technologies are essential to the safe and effective rollout of the APV and give the law enforcement officers another tool in combating emerging technologies. In addition to the APV, law enforcement agencies must find ways to leverage advanced technologies, essentially, staying one step ahead of the nefarious actor. Kill switch technologies should be a part of every APV platform and be available to all law enforcement officers in the near future.

3. Privacy Issues

As of 2018, the number of internet users in the world today totals approximately 3.010 billion, and more than 52% of the world’s population has access to the internet.²⁹¹ Several cities are beginning to utilize smart city technologies, whereas law enforcement agencies and other government entities will have greater access to private records and video feeds. In Chicago, “Operation Virtual Shield” was implemented to expand its surveillance cameras and other enhanced sensors throughout the city to help keep the city safe.²⁹² These cameras and sensors are fed into Chicago’s central operations center, which is accessible to public safety officials, and just one example of a major city transitioning to smart city technologies. As more and more communities become smart cities, the greater the amount of information becomes available to government agencies.

As with all emerging smart city technologies, privacy may be of a major concern for consumers while police officers are utilizing the APV.²⁹³ The APV would be a part of an IoT system, connected to other sensors and wireless networks where data would be

²⁹¹ Khalid Saleh, “How Much of the World Population Is Online—Statistics and Trends,” *Invesp* (blog), accessed January 15, 2019, <https://www.invespro.com/blog/world-population-online/>.

²⁹² “Technology,” City of Chicago, accessed October 14, 2018, <https://www.cityofchicago.org/city/en/depts/oem/provdrs/tech.html>.

²⁹³ Adel S. Elmaghraby and Michael M. Losavio, “Cyber Security Challenges in Smart Cities: Safety, Security and Privacy,” *Journal of Advanced Research* 5, no. 4 (July 31, 2014): 491–97.

continuously captured and processed. By using facial recognition, ALPRs and other scanners, data could potentially be extracted, such as “phone numbers, email accounts, messaging logs, address books, social media accounts, credit card details, etc., as well as inferred information such as home and work addresses.”²⁹⁴ A person’s activity may also be monitored and tracked at all times while in an APV. The APV will present challenges for both law enforcement and lawmakers alike when it comes to protecting the privacy of individuals. Law enforcement agencies, lawmakers, and the public will need to work together and discern how much information the APV will be allowed to capture. These privacy concerns must be addressed; however, the opportunities and benefits from utilizing the APV are too strong to ignore. It will be imperative that law enforcement agencies take a comprehensive approach to reducing the risk, while continuing to seek out this technology in the future.

4. Legal Considerations

As with numerous other technologies discussed in this thesis, the use of the APV will evolve much quicker than the law. However, the APV will also present additional legal challenges for law enforcement agencies. One way for law enforcement agencies to examine the legality of the APV is by analyzing court cases surrounding the complementary technologies and sensors that can be found on the platform. The landmark 1967 *Katz v. United States* case set the standard for defining the legal definition of a search.²⁹⁵ In this case, the FBI used information obtained from tapping a phone booth that the petitioner (Katz) was using. The information the FBI collected ultimately led to an arrest and conviction. The Supreme Court later ruled that it was unconstitutional “to conduct a search and seizure without a warrant anywhere that a person has a reasonable expectation of privacy unless certain exceptions apply.”²⁹⁶ This case has been

²⁹⁴ Rob Kitchin, *Getting Smarter about Smart Cities: Improving Data Privacy and Data Security* (Dublin, Ireland: Data Protection Unit, Department of the Taoiseach, 2016).

²⁹⁵ *KATZ v. U.S.*, 386 U.S. 954 (1967), <https://supreme.justia.com/cases/federal/us/386/954/>.

²⁹⁶ *KATZ*, 386 U.S. 954.

used extensively to evaluate the advancement of technology that poses new questions on the expectations of privacy.²⁹⁷

As discussed in this thesis, ALPRs have been used extensively by law enforcement agencies and will be a mainstay of the APV. The Supreme Court has on multiple occasions ruled “that there is no expectation of privacy” when it comes to vehicle license plates.²⁹⁸ Courts have “held that law enforcement officers may, at their own discretion and without reasonable suspicion, do at least an initial check of a license plate against a law enforcement database.”²⁹⁹ However, this verification may soon change. The Virginia Supreme Court ruled in April 2018 that photos taken by the APLR constitute personal information and may not legally be retained by law enforcement agencies.³⁰⁰ This case could very well have wider implications for law enforcement agencies in terms of how long they could keep the data generated by an ALPR.

Cameras utilized by facial recognition technologies will be employed by the APV to capture and analyze facial images of people in public places. Courts have never ruled on privacy as it relates to facial recognition, nor have they “formally recognized a reasonable expectation of privacy in public conduct.”³⁰¹ However, based on current case law, the Fourth Amendment does not provide protection for images captured in a public space.³⁰² Therefore, do not anticipate a reasonable expectation of privacy for any person on a street nor sidewalk or seen outside of a building or a vehicle. A warrant will be

²⁹⁷ Matthew Tokson, “Knowledge and Fourth Amendment Privacy,” *Northwestern University Law Review* 111, no. 1 (December 15, 2016): 139–204.

²⁹⁸ Rachel Levinson-Waldman, “Hiding in Plain Sight: A Fourth Amendment Framework for Analyzing Government Surveillance in Public,” Emory University School of Law, accessed September 10, 2018, <http://law.emory.edu/elj/content/volume-66/issue-3/articles/hiding-plain-fourth-amendment-government-surveillance-public.html>.

²⁹⁹ Levinson-Waldman.

³⁰⁰ Michael Booth, “Virginia Supreme Court Takes Aim at Random License Plate Scans by Police,” *National Law Journal*, May 4, 2018, <https://www.law.com/nationallawjournal/2018/05/04/virginia-supreme-court-takes-aim-at-random-license-plate-scans-by-police/>.

³⁰¹ University of Baltimore Law Review Staff, “Facial Recognition Technology: First and Fourth Amendment Implications,” *University of Baltimore Law Review* (blog), April 14, 2017, <https://ubaltlawreview.com/2017/04/14/facial-recognition-technology-first-and-fourth-amendment-implications/>.

³⁰² Matthew T. Mangino, “Matthew T. Mangino: Facial Recognition Technology and the Expectation of Privacy,” *Providence Journal*, July 27, 2018, <https://www.providencejournal.com/opinion/20180727/matthew-t-mangino-facial-recognition-technology-and-expectation-of-privacy>.

required for police officers when anything outside of public view is observed. Essentially, whatever the police officer and APV can see and observe in a public place does not have Fourth Amendment protection.

Courts have not ruled on Fourth Amendment protections for law enforcement's use of air sampling technologies. However, case law has been established for the use of police dogs. The APV will utilize its air sampling sensors similarly to how police dogs have been used by law enforcement agencies to detect bombs and narcotics. In 2004, the Supreme Court ruled in the *Illinois v. Caballes* case that use of a "narcotics-detection dog" during a "lawful traffic stop" did not violate the Fourth Amendment so long as the traffic stop is not excessively lengthened.³⁰³ Using this model, the APV would be able to employ its air sampling sensors during a legal traffic stop without violating the Fourth Amendment. This situation becomes complicated as to whether probable cause can be established when air sampling sensors are used in transient by law enforcement agencies. Since case law has not yet been established on this issue, law enforcement agencies should consider obtaining a search warrant prior to conducting a traffic stop to ensure the stop is legally binding.

The search of a person's home is held to a much higher standard under the Fourth Amendment than that of their vehicle. In the 2001 *Kyollo v. The United States* case, the Supreme Court ruled that the use of a thermal imaging sensor to "search" a house is a violation of the Fourth Amendment and "unreasonable without a warrant."³⁰⁴ However, less stringent requirements are needed for motor vehicles. The motor vehicle has an exemption that modifies the probable cause requirement of the Fourth Amendment. The exemption was established in the 1925 *Carroll v. United States* case that allowed a warrantless probable cause vehicle search by police officers.³⁰⁵ The exemption is based on the premise of a lower expectation of privacy in motor vehicles.

³⁰³ *Illinois v. Caballes*, 543 US 405 (Supreme Court 2004).

³⁰⁴ *Kyollo v. United States* (Opinion of the Court), 533 U.S. 27 (U.S. Supreme Court 2001).

³⁰⁵ *Carroll et al., v. United States* (1925), <https://www.law.cornell.edu/supremecourt/text/267/132>.

Furthermore, a motor vehicle's ease of mobility creates an inherent exigency to prevent the destruction or removal of evidence or contraband. In the 1996 *Pennsylvania v. Labron* case, the Supreme Court ruled that Fourth Amendment rights are not violated because the motor vehicle exception "requires only that there be probable cause to conduct a search."³⁰⁶ The scope of the vehicle search is limited to which area the police officer has probable cause to search. This area encompasses the entire vehicle including the trunk. The motor vehicle exemption also extends to any containers inside the vehicle that may contain evidence or contraband. The Tenth Court Appeals ruled in the 2011 *United States v. Ludwig* case that a search warrant was not even required even if with little risk of the vehicle being driven away.³⁰⁷ Other recent cases extending the motor vehicle exemption have been applied to trucks, trailers, boats, airplanes, and motor homes.

Based on current case law, the APV should not be significantly affected when used on patrol by law enforcement agencies. While courts have not considered the legality of the APV for law enforcement use, the motor vehicle exception, coupled with previous court decisions on complementary technologies, can assist law enforcement agencies with Fourth Amendments concerns. With this knowledge, police officers do not have to become legal experts on case law to use the APV; however, they must understand the legal ramifications already in place specific to complementary technologies that will make up the entire APV platform.

C. CHAPTER SUMMARY

Based upon the research in previous chapters on AV technology, complementary technologies, as well as the author's law enforcement experience, this chapter explored and discussed the potential benefits and concerns of the APV. The APV benefits included improving officer efficiency, officer safety, fugitive searches, rescue operations, community policing, and public safety communications. However, several potential APV

³⁰⁶ *Pennsylvania v. Labron*, 518 U.S. 938 (1996), <https://supreme.justia.com/cases/federal/us/518/938/>.

³⁰⁷ *United States v. Ludwig*, No. 10–8009 (U.S. 10th Cir. 2011), <https://caselaw.findlaw.com/us-10th-circuit/1564687.html>.

concerns were also raised. Some of these trepidations may include privacy and legal drawbacks, as well as the potential to weaponize the APV. The positive effects of the APV appear to outweigh the shortcomings and thus it can only be a matter of time before the APV is implemented by law enforcement agencies. However, prior to this implementation, law enforcement agencies must consider what the unintended consequences of the APV may be.

The next chapter synthesizes all the research thus far in this thesis and focuses on a series of plausible future APV scenarios to examine the unintended consequences of the technology. These scenarios focus on how the APV may function and impact the law enforcement officer during traffic stops, police pursuits, calls for service, fugitive searches, and community policing efforts.

V. ANALYSIS—IMAGINING THE UNEXPECTED

This chapter ties together all the APV research in this thesis and explores future law enforcement APV scenarios that will highlight how the law enforcement officer may be impacted. These scenarios are entirely fictional, including the subject names. Scenario analysis is a useful tool to utilize when confronted with “industry uncertainties.”³⁰⁸ This type of analysis helps to determine “both small and large ‘what-if’ outcomes.”³⁰⁹ The short scenarios in this chapter incorporate the potential benefits of the APV to paint a picture of how this advanced technology may be utilized by law enforcement agencies and how they may be used in more diverse ways than current police vehicles. Imagining these changes brought forth by the APV may lead to imagining how the police officer’s task, function, or mission may be impacted. While many of these changes are anticipated to be positive—increasing officer efficiency, reducing officer safety risks—unintended consequences to law enforcement agencies and officers may result. These unintended consequences may have the most impact to police officers.

A. SCENARIOS

The following three fictional scenarios demonstrate how the APV may be utilized by law enforcement agencies in the near future.

1. First Scenario: The Lone Patrol Officer

Prior to hitting the beat, Officer Elizabeth Lynch of the Springfield Police Department inspects her 2037 model year APV. She conducts a walk around visual inspection of the APV and then gets into the front seat to begin working through her pre-shift checklist. As she enters the vehicle, the APV immediately recognizes her by a retina scan and moves the front seat to her preferred position.

³⁰⁸ Grace Quiceno et al., “Scenario Analysis for Strategy Design: A Case Study of the Colombian Electricity Industry,” *Energy Strategy Reviews* 23 (January 1, 2019): 57–68, <https://doi.org/10.1016/j.esr.2018.12.009>.

³⁰⁹ River Logic, “Scenario Analysis: A Powerful Analytics Force,” *River Logic* (blog), April 8, 2016, <https://blog.riverlogic.com/scenario-analysis-a-powerful-analytics-force>.

Officer Lynch logs on via voice request to the department CAD system and programs the APV to patrol the riverfront area of Springfield.

The APV leaves the rear lot of the police department and drives itself towards the riverfront area of the city. The APV is not only driving and monitoring for service calls on the CAD system but also utilizing its sensor network to scan for criminals and crimes in progress. While the APV is patrolling, Officer Lynch reads the briefing log to see what happened in the previous eight hours. As she is reading the log, she reflects about how officers 20 years ago not only had to drive themselves while looking at the CAD screen, but also had to operate the emergency lights and siren while talking on the radio. The role of a police officer has drastically changed with the advent of the APV. The technological advances of the autonomous vehicle have made the roads safer and of course have led to fewer traffic stops over the last several years. The APV has allowed law enforcement agencies to utilize the AV technology to focus on fighting crime and stopping criminals rather than on maneuvering and being distracted by their patrol vehicles.

While Officer Lynch is reminiscing, the APV comes to a complete stop at a four-way intersection at Sunset Boulevard and Grand Avenue. The APV clears the intersection and proceeds forward when suddenly a human-driven 2018 sport utility vehicle (SUV) speeds through the stop sign at the intersection and forces the APV to brake hard and swerve to avoid a collision. Immediately, the APV's sensor network comes to life as the APV's camera captures the driver's face while simultaneously scanning the SUV's license plate. The APV uploads the photo and the license plate and compares them against a national cache of images. The images quickly produce high-probability matches. The captured image of the driver, combined with the license plate data, helped the APV identify Bobby Smith, a two-time felon, who is the brother of the SUV's registered owner. Smith has multiple arrests and a history of assaults, kidnapping, and armed robbery. Smith's photo and criminal history are displayed on the CAD screen for Officer Lynch to review. A brief moment later, the APV receives uploaded surveillance

images from nearby Hometown Bank, which depict Smith pointing a handgun at the bank teller.

Officer Lynch promptly directs the APV via voice commands to follow and conduct a traffic stop on the SUV. The APV responds to the voice commands quickly and immediately activates its emergency lights and siren while conducting a U-turn to position itself behind the SUV. The APV accelerates to 100 mph to catch up to the SUV. As the APV approaches the SUV, it confirms Smith is the lone occupant by utilizing its thermal imaging sensors to scan the SUV. As the APV is pursuing the SUV, it becomes apparent to Officer Lynch that Smith will not pull over voluntarily. If Smith were driving an AV, she could easily shut down the vehicle with the APV's kill switch, but alas, the SUV is 19 years old and she will have to rely on other methods to stop the SUV. She instructs the APV to conduct a precision immobilization technique (PIT) maneuver when it is safe to do so. The APV accelerates and moves up just to the right rear of the SUV. As soon as the SUV slows slightly, the APV conducts the PIT maneuver and forces the SUV to the side of the road.

Smith hastily exits the vehicle and makes a run for a large field to the east of their location. Officer Lynch instructs the APV to launch its UAS to follow Smith into the field. Smith jumps a chain-linked fence and continues running to a dense patch of bushes and attempts to hide from Officer Lynch. The UAS immediately moves over Smith's position and casts his image and location onto the APV's CAD screen. All the while, Officer Lynch stays with the APV and waits for backup. She thinks back again to what it must have been like to have several officers on patrol at once and immediate backup when needed. Since the APV came to fruition, her police department has downsized over the last several years and officers on patrol must cover so much more area than they used to; all because the APV has allowed the police department to do more with less. Officer Lynch accomplishes so much with the APV and rarely needs backup, so she assumes the benefits outweigh the costs. She knows that Smith cannot hide from

her or the APV, so she will continue to wait patiently until another officer can assist her in making an arrest.

2. First Scenario Summary

This scenario depicts the daily activities of a typical patrol officer in an autonomous world by exemplifying how the APV operates and simultaneously employs its wireless sensor platform. The benefits the APV presents to law enforcement agencies are plentiful. For instance, Officer Lynch utilizes all the available technology the APV has to offer while on patrol to make her job more efficient while also increasing her overall safety. The APV helps her avoid a traffic collision while engaging in the pursuit of a fleeing suspect. It furthermore is able to process large amounts of data quickly to keep Officer Lynch informed of any potential threats or risks while on patrol. Finally, the APV is able to communicate seamlessly with other emergency response vehicles while helping Officer Lynch secure the scene at the end of the pursuit. While these aspects are all positive for an APV implementation, this scenario also points out the negative connotations APV technologies may have on the workforce of a law enforcement agency. While it is assumed that the APV's technology will have capabilities that will surpass anything that humans can perform alone, this nuance may equate to a diminished or reallocated police workforce. Officer Lynch is experiencing the downfall of a shrunken police workforce at the end of her pursuit because she has to wait for backup.

3. Second Scenario: The Skilled Community Officer

Officer Sam Geletko told the mechanic at his office he would bring back his assigned APV tomorrow so that the maintenance service could be completed. Officer Geletko knew he probably should have waited for the maintenance service to be completed, but he just could not wait to get out there on his walking beat. Besides, what would the harm be if he pulled his APV out of service earlier? He never had any problems with the APV in the past and wanted to get on his beat in the community earlier than the day before.

Officer Geletko has been assigned as a Springfield Community Officer for the last four months. He applied for the position after several years of working patrol. He

wanted a change of pace and knew he was probably out of a job if he stayed on patrol due to the implementation of the APV. Some fortunate police officers, such as himself, were reallocated to different jobs in the department, such as community officer positions. Officer Geletko was excited about the transition because he knew it would help his police department get back to its roots and build community-police partnerships while allowing him to keep his job as a police officer.

Officer Geletko enters the vehicle and instructs his APV to drive downtown to his assigned walking beat. While his APV is driving, Officer Geletko thinks back to when he was a new police recruit. He remembers having to drive at the police academy but has rarely done it since. In fact, he cannot remember the last time he has driven. Most of the vehicles on the road today are autonomous, including his own personal vehicle. He did not really like having to drive anyway; it just seemed tedious and inefficient. He was glad he would never have to do that again.

As his APV turns onto Main Street, he directs the APV to stop. Officer Geletko enjoys being on Main Street, as it is filled with several family owned businesses and restaurants. He likes to start his day talking to the community members in Bean's Coffee Shop located on the corner. He programs his APV to "Community Foot Patrol" and exits the vehicle. In this mode, the APV will follow along with Officer Geletko as he walks on the sidewalk. If the APV is not able to follow due to limited space on the road, it will travel a block ahead to park and wait for Officer Geletko to advance on foot. The APV knows Officer Geletko's location and is constantly performing 360 surveillance for situation awareness. In this capacity, the APV serves as a mobile communication center and reports suspicious activities to both Officer Geletko and the Springfield dispatch center.

Officer Geletko enters Bean's Coffee Shop and orders a large latte to go. While in the coffee shop, his APV alerts him to Officer Lynch's pursuit. Officer Lynch is requesting backup and his APV advises that he is the closest unit to assist her. He wonders how he could be the closest unit when he is over 10 miles away. He surmises that the recent layoff of patrol officers had something to do with it and

he should not be complaining since he has a job. Over the radio, and via voice command, he directs the APV to meet him outside the coffee shop. He quickly grabs his latte and heads out the door.

The APV is slow to respond as it drives towards Officer Geletko's location. Officer Geletko realizes this slowness as well but does not have time to think about it. He enters the APV and instructs the vehicle to drive to Officer Lynch's location. However, the APV does not respond. He instructs the APV once again to respond "code-3," but the APV replies back that its autonomous driving mode is malfunctioning and its navigation system is "unavailable at the present time." Officer Geletko slams his fist on the dashboard and orders the APV to drive. The APV responds with "manual driving mode is available."

Officer Geletko begins to panic; he knew he should have left the APV in for service. What is he going to do now? He is not comfortable driving the APV in manual mode, and he is not even sure how to get to Officer Lynch's location without the aid of the APV's navigation system. He decides it is probably safer if he stays put and calls for a tow truck to take him back to the station. Officer Geletko notifies his dispatch center he is "out of service" and requests a tow truck to his location. He feels bad he cannot assist Officer Lynch, but figures she would understand given the circumstances. He reminds himself that he needs to brush up on his manual driving skills should this situation ever happen again.

4. Second Scenario Summary

This scenario illustrates how the APV may alter or enhance other areas of police work. Officer Geletko, as a Springfield Community Officer, is able to participate in community-centered policing proactively that may not have been possible prior to the APV. Officer Geletko employs his APV as his partner while walking on his assigned beat. The APV is able to keep Officer Geletko informed by performing consistent surveillance for situational awareness while concurrently communicating with other officers and dispatch centers to report suspicious activities. The APV serves as Officer Geletko's mobile police station so he can focus on increasing community interactions.

While this scenario portrays how the APV can positively augment community relations, it also sheds light on how officers may become dependent on APV technology and thus lose a desirable skillset. Additionally, it reinforces the requirement for officers to remain aware of equipment maintenance cycles.

5. Third Scenario: The Technical Commercial Officer

Sergeant Kyle Marquez was already on his third commercial vehicle inspection for the day, and it was only 7:30 am. He did not mind working hard, as he was a diligent employee and was thankful to be a police officer for the Springfield Police Department. He had always wanted to be a police officer, but the job had become very difficult to obtain. Due to advanced police technologies, such as the APV, police officers needed to have a strong IT skillset. Prior to becoming a police officer, Sergeant Marquez was a computer systems analyst for Springfield Steel Industries. However, he knew that this experience would not be enough to become a police officer so he went back to the University of Washington to obtain his master's degree in computer science.

Sergeant Marquez quickly caught the attention of his supervisors, as he not only was a conscientious employee, but he was at ease with advanced police technologies. He was assigned several increasingly difficult positions the last several years and was swiftly promoted to Sergeant in the high-profile commercial unit. Since most commercial trucks were autonomously driven, they had become the focal point for criminals transporting illegal drugs or stolen goods across the country. The commercial unit was responsible for ensuring the safe operation of commercial traffic throughout the city, while mitigating illegal commercial activity.

Since becoming a member of the commercial unit, Sergeant Marquez has been responsible for several high-profile arrests. Two years ago, while on patrol, Sergeant Marquez' APV alerted him of a suspicious truck headed to Utah. The APV's sensor network detected radioactive material in the trailer, which was not on the truck's bill of lading. Sergeant Marquez inspected the truck and found

iridium-192 onboard. The iridium-192 was purchased on the black market and was headed to Utah to become part of a larger dirty bomb. The dirty bomb was meant to be used in an attack on Mile High Stadium during a Denver Broncos playoff game. Sergeant Marquez' inspection potentially saved the lives of over 75,000 people.

In another incident, Sergeant Marquez' utilized his APV's TTWS technology that alerted him of motion in the back of a tractor-trailer. Sergeant Marquez stopped the truck and inspected the trailer. He was alarmed to find over 60 female immigrants clinging to life. He immediately coordinated their safe recovery while investigating how they were placed on board. He ultimately uncovered a large-scale human trafficking ring in which the female immigrants were being used for commercial sexual exploitation. His investigation resulted in 22 arrests and the safe recovery of over 150 female immigrants.

Sergeant Marquez loved traveling in the APV and considered the technology and platform a true partner. He counted on the APV to be his eyes and ears when he was on patrol or inspecting commercial trucks. Today, his APV had already alerted him to three overweight commercial vehicle violations, and all before 8 am. He was wrapping up the third commercial inspection when his APV alerted him that Officer Lynch was asking for backup. He was on the outskirts of the city and assumed another officer would be closer. His APV told him that Officer Geletko was closer and would be responding, so Sergeant Marquez went back to work. However, after a few moments, his APV alerts him that Officer Geletko is "out of service" and he is the next closest unit. Sergeant Marquez closes out his inspection and sends the commercial truck on its way.

He enters his APV and directs it to Officer Lynch's location, "code-3." Sergeant Marquez' APV tells him it will take approximately eight minutes to arrive at her location with the current traffic conditions.

While traveling to the location, Sergeant Marquez reviews the details of Officer Lynch's pursuit including the relevant information on her suspect, Bobby Smith.

His APV receives an immediate upload from Officer Lynch's APV of where the suspect is hiding and the safest way to approach the location. Sergeant Marquez is also informed that Officer Lynch's APV has already notified all emergency response vehicles in the area of the pursuit. Two EMS vehicles responded and are located at a safe location near Officer Lynch in case they are needed. The APV has logged their location on scene.

Sergeant Marquez arrives on scene in seven minutes and 52 seconds. His APV immediately alerts Officer Lynch of his arrival. Once on scene, he communicates directly with Officer Lynch. With the UAS still overhead, they approach the suspect with their guns drawn. They order the suspect out and tell him he is surrounded. After a few minutes, Bobby Smith grudgingly exits his hiding place and submits to the arrest. EMS medical personnel treat Bobby Smith on scene for some minor scrapes and scratches and he is loaded into the back of Officer Lynch's APV. Officer Lynch thanks Sergeant Marquez for his help and instructs the APV to drive to the jail for booking while she begins the booking paperwork. Sergeant Marquez returns to his APV and tells it to resume "Commercial Traffic Patrol."

All in a good day's work for the Springfield Police Department.

6. Third Scenario Summary

This scenario portrays the enhanced capabilities the APV may present to law enforcement agencies. Sergeant Marquez is able to crack two high profile cases using the APV's heightened sensor network. These crimes may not have been solved if not for the APV's air sampling and TTWS technology systems. While these technologies are available now as stand-alone systems, they are not being utilized in a multi-layered platform, such as the APV. In addition, Sergeant Marquez' APV is readily available to assist Officer Lynch by interacting with her APV and other emergency response vehicles in establishing a parameter at the scene of the pursuit. The take away from this scenario is how the APV becomes a force multiplier if law enforcement agencies are able to successfully leverage the emerging technology. The scenario also highlights how law

enforcement officers in an autonomous world may require a strong IT background to be successful. Advanced technologies may require additional training for new patrol officers.

B. SCENARIO FINDINGS AND UNINTENDED CONSEQUENCES

The previous section's futuristic scenarios illustrate the APV's essential benefits to both law enforcement agencies and personnel. Conversely, this section touches on some of the potential APV drawbacks that may impact the law enforcement officer. Drawing on the research from AV technologies, and UAS and wireless sensor network technologies discussed in the previous chapters, this section proposes some conceivable unintended consequences that may be realized with the advent of APV technology. While the benefits and drawbacks of the APV cannot be predicted with complete confidence at this stage of development, some unintended consequences can be identified to be mitigated or prevented by law enforcement agencies considering the APV.

Given that APV technology will have capabilities that will surpass anything that humans can perform alone, the first unintended consequence may be a reduced or reallocated police workforce. The second unintended consequence is having law enforcement officers potentially lose a skill set, such as driving or navigating, both of which are the cornerstone of today's police officers. Finally, the last unintended consequence for law enforcement agencies may be a shifting workforce. The advanced technologies and sensor networks on the APV may require agencies potentially to change their hiring practices to recruit more officers with a strong IT background. All three of these unintended consequences will significantly impact the future law enforcement officer. The following subsections discuss these unintended consequences in greater depth.

1. Technological Unemployment

A 2016 study by the Bureau of Justice Statistics shows the "average number of full-time sworn officers per 1,000" in the United States has decreased 11%, from 2.42 in

1997 to 2.17 in 2016.³¹⁰ However, “the number of full-time sworn officers in general-purpose law enforcement agencies increased by about 52,000 (up 8%).”³¹¹ Essentially, the population of the United States has increased at such a rate that law enforcement agencies have not been able to hire at a comparable pace, as fewer police officers per capita are available today than in 1997. These numbers are bound to get even more dire in the coming years, as the desire to become a police officer has recently waned.³¹² According to a recent *Washington Post* article, hiring and retention of police officers has become more difficult because of both media scrutiny and the perceptions of policing.³¹³ Across the nation, law enforcement agencies are receiving fewer applications. In Seattle, applications have plummeted by almost 50%, while Nashville applications were down by almost 60%.³¹⁴ However, Chuck Wexler, the executive director of the Police Executive Research Forum, believes that the decrease in staffing per capita and reduced hiring has more to do with greater police efficiencies across the nation.³¹⁵

Efficiency and technology are often intertwined in the law enforcement realm. Cities, such as San Jose and Oakland, are using technologies, for example, body worn cameras, ALPRs, and facial recognition to maximize their operating efficiencies while dealing with a shortage of police officers.³¹⁶ The technology has allowed them to do more with less. Other law enforcement agencies could also benefit from emerging technologies, and thus, it would be easy to visualize how agencies dealing with staffing shortages would benefit from the implementation of the APV. The APV would be a force

³¹⁰ Shelley Hyland, “Full-Time Employees in Law Enforcement Agencies, 1997–2016,” Bureau of Justice Statistics, August 28, 2018, <https://www.bjs.gov/index.cfm?ty=pbdetail&iid=6366>.

³¹¹ Hyland.

³¹² PoliceOne Staff, “Police Job Applications Decrease at Most U.S. Departments,” December 6, 2018, <https://www.policeone.com/recruitment-retention-crisis/articles/482289006-Police-job-applications-decrease-at-most-U-S-departments/>.

³¹³ Tom Jackman, “Who Wants to Be a Police Officer? Job Applications Plummet at Most U.S. Departments,” *Washington Post*, December 4, 2018, https://www.washingtonpost.com/crime-law/2018/12/04/who-wants-be-police-officer-job-applications-plummet-most-us-departments/?noredirect=on&utm_term=.02b31e872677.

³¹⁴ Jackman.

³¹⁵ Jackman.

³¹⁶ George Avalos, “Police Use New Technologies to Fight Crime,” *Government Technology*, January 18, 2016, <http://www.govtech.com/dc/articles/Police-Use-New-Technologies-to-Fight-Crime.html>.

multiplier for law enforcement agencies by allowing them to be more efficient while capitalizing on the platform's advanced technologies and sensor networks.

Finding the right balance between efficiency and staffing levels has always been a challenge for law enforcement agencies and the introduction of the APV will increase this challenge. While the cost of the APV has not been discussed and is unknown at this time, the average nationwide police officer's salary in 2017 was \$62,960 and as high as \$122,000 in California.³¹⁷ Law enforcement agencies might be quick to shed some of these salaries and lower their operating costs. However, the need to fill a staffing void or to reduce operating costs with advanced technologies may lead to an even greater shortage of personnel and create technological unemployment.

Technological unemployment is caused when jobs are lost due to the advancement of technology.³¹⁸ In other words, using technology in place of manpower results in technological unemployment. During the 2015 World Summit in New York City, several prominent individuals and organizations in science and technology met to discuss the consequences of "technological unemployment."³¹⁹ During the summit, it was suggested, "accelerating technological unemployment will likely be one of the most challenging societal issues in the twenty-first Century."³²⁰ In addition, the summit concluded, "billions of people worldwide are currently employed in industries that will likely be affected—and billions of new entrants to the workforce will need jobs."³²¹ Advancing digital technologies have already helped companies "overcome many limitations rapidly," and are making inroads today similar to how the steam engine disrupted the Industrial Revolution.³²²

³¹⁷ "Police and Detectives: Occupational Outlook Handbook," Bureau of Labor Statistics, last modified February 15, 2019, <https://www.bls.gov/ooh/protective-service/police-and-detectives.htm>.

³¹⁸ Michael A. Peters, "Technological Unemployment: Educating for the Fourth Industrial Revolution," *Educational Philosophy and Theory* 49, no. 1 (January 2, 2017): 1–6, <https://doi.org/10.1080/00131857.2016.1177412>.

³¹⁹ "The World Summit on Technological Unemployment," World Technology Network, April 24, 2015, <https://www.wtn.net/technological-unemployment-summit>.

³²⁰ World Technology Network.

³²¹ World Technology Network.

³²² Peters, "Technological Unemployment."

As depicted in *The Lone Patrol Officer* scenario, the APV may significantly reduce the need for police officers. While this reduction may seem like a natural progression, fewer police officers may lead to increased officer safety risks. The APV may mitigate traffic safety risks for the officer while increasing overall efficiency, but it also means fewer officers available for backup. For those few officers working the beat together, it may also mean longer wait times for backup to arrive. Officer Lynch was alone for almost eight minutes before backup arrived. While this wait does not seem like a long time, it can seem like an eternity for the officer waiting in a precarious situation. Law enforcement agencies must consider this potential situation when considering APV polices and the impact to their personnel; otherwise, officers may need to get used to waiting and working alone for longer periods of time.

2. Lost Perishable Skills

Emerging technologies have the potential to enhance U.S. society, but they also have the ability to be a hindrance as well. APV technology may fuel law enforcement efficiency, organization, and communication efforts but may also impact valuable perishable skills along the way. One specific skill that may be diminished is driving, which is an essential skill for today's police officer. The APV is expected to reduce police vehicle collisions and traffic related incidents, but as depicted in the *Skilled Community Officer* scenario, what happens when the APV fails and the police officer is forced to take over manual control of the platform? Officer Geletko was uncomfortable having to take over the manual operation of the APV because he did not feel safe doing so. He trusted the APV to drive better than he could, and thus, had to go "out of service."

Police officers throughout the country drive in both urban and rural locations when responding to emergency calls and utilizing emergency driving skills. Current law enforcement officers are some of the best-trained drivers in the nation due to their academy training on the physics of driving a vehicle, as well as the psychology of police driving.³²³ Police driving skills include navigating high-speed vehicles and utilizing

³²³ "Police Are in Hot Pursuit of Driving Skills," PoliceOne, May 3, 2002, <https://www.policeone.com/archive/articles/51319-Police-are-in-Hot-Pursuit-of-Driving-Skills/>.

evasive and defensive driving skills.³²⁴ However, these skills are perishable if not practiced and applied often. When the APV begins braking automatically in emergency situations and safely chases a fleeing suspect at high speed, it is safe to assume this skillset may be lost. Essentially, by using automated aids to improve traffic safety, the APV will have the unintended consequence of “degrading driving skills.”³²⁵ AV automakers are already beginning to worry about this scenario. Adrian Lund, the president of the Insurance Institute for Highway Safety, is concerned people will begin to check out and pay less attention to driving skills when the driving tasks become easier.³²⁶ In fact, consumers believe their own driving skills will erode once automated vehicles become more prominent. In an informal survey conducted by Kelley Blue Book’s online website, “fifty-seven percent said driver-assist technologies will eventually erode driving skills.”³²⁷

The loss of driving skills may also be attributed to an increasing trust in technology. A University of Michigan study determined that drivers utilizing blind-spot detection systems “failed to look over their shoulder to check for themselves when changing lanes.”³²⁸ As more drivers become familiar with autonomous systems, they “can quickly learn to rely on them, or assume they work better than they actually do.”³²⁹ In emergency situations, people may begin trusting the automated systems more than themselves.³³⁰ A recent collision investigation demonstrates this shift. In 2016, a Tesla Model S was being tested in semi-autonomous autopilot when it collided with a tractor-trailer that resulted in the death of the Tesla driver. A federal investigation concluded that

³²⁴ PoliceOne.

³²⁵ Keith Naughton, “Robots Are Ruining Your Driving Skills,” August 10, 2017, Bloomberg, <https://www.bloomberg.com/news/articles/2017-08-10/as-robots-take-the-wheel-driving-skills-begin-to-hit-the-skids>.

³²⁶ Naughton.

³²⁷ Naughton.

³²⁸ Kristen Lee, “It’s True: Self-Driving Cars Will Make Our Driving Skills Even Worse,” Jalopnik, August 10, 2017, <https://jalopnik.com/its-true-self-driving-cars-will-make-our-driving-skill-1797709144>.

³²⁹ Dee-Ann Durbin, “Fatal Tesla Crash Could Slow Automakers’ Race toward Driverless Cars,” *Portland Press Herald*, July 1, 2016, <https://www.pressherald.com/2016/07/01/fatal-tesla-crash-could-slow-automakers-momentum-toward-driverless-cars/>.

³³⁰ Naughton, “Robots Are Ruining Your Driving Skills.”

the “Model S was in autopilot for 37.5 minutes.”³³¹ While in autopilot, the driver only had his hands on the wheel for a total of 30 seconds.³³² The driver could have taken control of the vehicle at any time, but it appeared he believed that the Tesla would take evasive action and be able to maneuver away from the tractor-trailer.

History has shown that drivers can lose valuable driving skills as automobile technology has increased. An example would be the decline of vehicles sold in the United States with manual transmissions. Manual transmissions were popular for lower costs, greater fuel economy, and increased durability.³³³ Yet, automakers have advanced the automatic transmission to make them “quicker, more efficient, much easier to operate, and better than most drivers.”³³⁴ Essentially, this advancement has taken control away from the driver, “for the sake of automation.”³³⁵ In 2006, 47% of vehicles introduced by automobile manufacturers were offered in both automatics and manuals. In 2018, it was down to 20% and declining rapidly. In fact, only 2% of all vehicles sold in 2018 were equipped with manual transmissions.³³⁶ As drivers have been introduced to modern automakers, fewer are learning to drive a manual transmission. The percentage of drivers who know how to drive a manual transmission has steadily decreased to approximately only 18%.³³⁷ It is astonishing to envision 82% of automobile drivers not knowing how to drive a manual transmission. They would be stuck in the same place as Officer Geletko when confronted with a vehicle they did not feel safe to drive. They would have to wait for a tow truck or other assistance.

³³¹ Cadie Thompson, “New Details about the Fatal Tesla Autopilot Crash Reveal the Driver’s Last Minutes,” *Business Insider*, June 20, 2017, <https://www.businessinsider.com/details-about-the-fatal-tesla-autopilot-accident-released-2017-6>.

³³² Thompson.

³³³ Eric C. Evarts, “Why Are Manual Transmissions Disappearing?” *U.S. News & World Report* (blog), September 27, 2016, <https://cars.usnews.com/cars-trucks/best-cars-blog/2016/09/why-are-manual-transmissions-disappearing>.

³³⁴ Robert Duffer, “The Shift Is on: Manual Transmissions May Be Endangered but They’re Also Beloved,” *Chicago Tribune*, July 11, 2018, <https://www.chicagotribune.com/classified/automotive/sc-auto-cover-manual-transmissions-20180710-story.html>.

³³⁵ Duffer.

³³⁶ Duffer.

³³⁷ Evarts, “Why Are Manual Transmissions Disappearing?”

Law enforcement officers may get so accustomed to APV technology that they forget how to drive or do not feel safe driving without it. Driving is a perishable skill that must be practiced to be maintained. It is something law enforcement officers do not think much about today because they are always driving. In a typical 8-hour shift, police officers may drive nearly 100 miles a day, which equates to 2,000 miles a month or 24,000 miles a year of driving for a police officer.³³⁸ The APV would replace these thousands of miles of hands on practice each year with automated driving. This skillset may not erode immediately and may take several years after the implementation of the APV for this skillset to be lost; however, it is something law enforcement agencies must consider today to mitigate this risk in the future.

3. Shifting Hiring Practices

As depicted in the *Technical Commercial Officer* scenario, the APV will present a significant advancement in law enforcement technologies. Sergeant Marquez already had a strong IT background but needed an advanced degree to become a police officer. While law enforcement agencies must be concerned about technological unemployment, they must also understand that the future police officers must live in a digital world. The increasing use of advanced technologies will challenge law enforcement personnel to keep up. Current law enforcement officers may have a significant learning curve to overcome and new hires must have the technical background to hit the ground running. Law enforcement officers are already struggling to keep pace with the capabilities of current police IT, and the APV may force law enforcement agencies to rethink their current hiring practices.³³⁹

Law enforcement officers already have a significant IT skills gap, as “all officer and police staff should have the rudimentary skills to use operational technology and

³³⁸ “Ask A Cop: How Much Mileage Is Put on a Police Car?” Pamplin Media Group, December 25, 2014, <https://pamplinmedia.com/lor/48-news/244840-112074-ask-a-cop-how-much-mileage-is-put-on-a-police-car>.

³³⁹ Derek du Preez, “Police Watchdog—‘Forces Not Keeping Pace with Technology,’” Diginomica Government, March 3, 2017, <https://government.diginomica.com/2017/03/03/police-watchdog-forces-not-keeping-pace-technology/>.

should be aware of emerging digital trends.”³⁴⁰ Unfortunately, this problem is twofold, as current police training is “not effectively targeting these skill gaps,” and police officers are not hired for their IT expertise.³⁴¹ In a new report from the think tank Reform, police chiefs should consider firing staff who are not computer literate or who lack IT skills.³⁴² The reason behind this rationale is that law enforcement agencies need people with IT skills to be better prepared to handle the rise of cybercrime and other technology related crimes.³⁴³ While a broad expertise base is still needed by a police officer, IT skills are crucial in combating the digital face of crime.³⁴⁴

The core mission of law enforcement has not changed, as it is still focused on protecting the public while preventing crime and keeping the peace. However, if law enforcement agencies want to continue to be effective, they will have to “develop a more agile workforce and rely on an increasingly expanded ecosystem of partners.”³⁴⁵ The future workforce of law enforcement agencies will be diverse, agile, and “understand how to use technology.”³⁴⁶ While law enforcement agencies may resist change and be skeptical of technology, the future agency must look much different from its predecessors to be successful.³⁴⁷ For this change to occur, law enforcement agencies must create a “digital police brand” by recruiting more officers with an IT background.³⁴⁸

³⁴⁰ “REFORM—A Digital Response,” Blue Lights Digital, September 15, 2017, <https://bluelightsdigital.com/reform-review/>.

³⁴¹ Blue Lights Digital.

³⁴² Blue Lights Digital.

³⁴³ Fred S. McChesney, “Fewer Fires, so Why Are There Far More Firefighters?” *Washington Post*, September 4, 2015, https://www.washingtonpost.com/opinions/2015/09/04/05316abe-517c-11e5-933e-7d06c647a395_story.html?utm_term=.491be99e2504.

³⁴⁴ Blue Lights Digital, “REFORM—A Digital Response.”

³⁴⁵ “Reimagining the Police Workforce: Future Vision,” Accenture, September 26, 2018, <https://www.accenture.com/us-en/insights/public-service/reimagining-police-workforce-future-vision>.

³⁴⁶ Theo Douglas, “Report: As Tech Changes Law Enforcement, Its Workforce Must Adapt,” *Government Technology*, October 16, 2018, <http://www.govtech.com/public-safety/Report-As-Tech-Changes-Law-Enforcement-Its-Workforce-Must-Adapt.html>.

³⁴⁷ Douglas.

³⁴⁸ Blue Lights Digital, “REFORM—A Digital Response.”

The key for law enforcement agencies could be to “target digital recruitment strategies” that could entice more technology savvy applicants.³⁴⁹ Law enforcement agencies often seek out applicants who have college degrees in social sciences, or criminal justice; however, computer science or IT is rarely seen as a viable degree. In a recent survey of 309 police and law enforcement agencies around the world, “only 40 percent of those surveyed rated their police force’s recruitment strategy as effective, calling hiring new recruits vital to the future.”³⁵⁰ Law enforcement agencies must take these concerns to heart and rethink their specific recruitment strategies to entice perspective applicants with a strong IT background. This strategy will be paramount not only for the successful implementation of the APV, but also for the future roll out of advanced police technologies.

C. CHAPTER SUMMARY

This chapter’s scenarios highlighted specific law enforcement advantages of the APV, such as increased efficiency, improved communication, enhanced safety, and enriched community relations. The scenarios allow law enforcement agencies to imagine the benefits of the APV and its effects on their officers. However, the greater impact to law enforcement officers may be imagining the unintended consequences emphasized in these same scenarios, such as technology unemployment, degraded perishable skills, and shifting hiring practices. These unintended consequences should not be overlooked when law enforcement agencies begin contemplating the APV.

The next chapter discusses how law enforcement agencies may mitigate some of these unintended consequences, as well as a discussion for further APV research.

³⁴⁹ Blue Lights Digital.

³⁵⁰ Blue Lights Digital.

VI. RECOMMENDATIONS AND CONCLUSION

This final chapter explores how law enforcement agencies may mitigate some of the unintended consequences of the APV and its effect on law enforcement officers. The chapter recommends that law enforcement agencies recognize their officers' roles are bound to change and that they must pivot to become indispensable in the future. This viewpoint is examined by looking at how other public safety organizations have successfully adjusted to emerging technologies.

A. THE INDISPENSABLE PIVOT

Law enforcement agencies should follow the “lean strategy” approach and be prepared to pivot to remain indispensable. According to Ries, “a pivot” is “a structured course correction designed to test a new fundamental hypothesis about the product, strategy and engine of growth.”³⁵¹ Establishments not able to pivot get stuck “in the land of the living dead” and do not move forward.³⁵² The APV will potentially change the police workforce and present an opportunity for law enforcement agencies to pivot and move in a new direction. Pivoting to be indispensable has been the key to survival for both public and private organizations.

Several companies over the years, such as IBM, Shell, Nokia, Western Union, American Express, and Apple have made themselves indispensable by pivoting and adapting well to evolving technologies. They continue to be successful today by adapting to new technologies and the needs of their customers. Companies, such as Kodak, Blockbuster, and Borders failed to embrace technologies emerging within their industry and failed miserably. While these examples are from private sector companies that rely on a bottom line, the same can still be said for organizations in the public sector. The United States Postal Service (USPS) is an example of a government agency that has been

³⁵¹ Eric Ries, *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses* (New York: Crown Business, 2011), 149.

³⁵² Ries, 149.

“dying a slow death since the advent of email.”³⁵³ First-class mail is down 40% since 2000, and competitors, such as FedEx and UPS, have picked up much of its business.³⁵⁴ While the USPS continues to exist and deliver the mail, it has continually failed to meet its performance standards. In 2016, the Postal Regulatory Commission issued a report that found the USPS failed to meet its performance standards for all first-class services and most standard mail services during 2015.³⁵⁵ Performance shortfalls continue to trend downward annually and customers have continued to lose faith in the service.³⁵⁶ The USPS has failed to adapt to the latest in technology or make itself indispensable to its customers and stakeholders.

Some government agencies have pivoted and adapted well to new technologies and continue to thrive. An example is law enforcement’s brother in public safety, the Fire Department. Structure fires routinely used to destroy towns and cities in the United States. Fires nearly obliterated Detroit in 1805, Chicago in 1871, Boston in 1872, and San Francisco in 1906. However, over the years, the number of fires fought by fire departments has sharply decreased, due to advancements in technology. Building codes have evolved, as structures are now made from fire-resistant materials and are equipped with sprinklers and smoke alarms. According to the National Fire Protection Association (NFPA), half as many fires occur in the United States today than 30 years ago.³⁵⁷ In some major cities, the percentage is even greater. For example, in 1975 Boston, 417 major fires were reported, yet in 2012, only 40 major fires were reported, a decrease of 90%.³⁵⁸ Due to the decrease in fires, it would be a safe assumption to imagine the number of

³⁵³ Julie Sue Auslander, “Adapt or Die, The Enduring Rule of Innovation,” *Fast Company*, January 23, 2012, <https://www.fastcompany.com/1810048/adapt-or-die-enduring-rule-innovation>.

³⁵⁴ “First-Class Mail Volume since 1926,” United States Post Office, March 2018, <https://about.usps.com/who-we-are/postal-history/first-class-mail-since-1926.htm>.

³⁵⁵ Post Regulatory Commission, *Annual Compliance Determination Report—Fiscal Year 2015* (Washington, DC: Post Regulatory Commission, 2016), 3.

³⁵⁶ Post Regulatory Commission, 3.

³⁵⁷ “Data, Research, and Tools,” National Fire Protection Association, accessed October 5, 2017, <http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics>.

³⁵⁸ Leon Neyfakh, “Plenty of Firefighters, but Where Are the Fires?” *Boston Globe*, September 7, 2013, <https://www.bostonglobe.com/ideas/2013/09/07/plenty-firefighters-but-where-are-fires/isCPrIPauX078UKHdixu0K/story.html>.

firefighters in the United States has also decreased at a similar rate. However, this assumption is not true.

Although half as many fires occur today, those paid to fight fires has increased by roughly 50%.³⁵⁹ In 2013, firefighters responded to 487,500 structure fires in the United States, “which means each of the nation’s 30,000 fire departments saw just one fire every 22 days, on average.”³⁶⁰ So, how have fire departments been able to increase the number of firefighters over the years, while fighting fewer fires? They have adapted to evolving technology and shifted their focus to EMS incidents to remain indispensable.³⁶¹ According to Dennis Compton, the former chairman of the Executive Board of the International Fire Service Training Association (IFSTA), this shift has, “occurred steadily over the past four decades or more—and not by accident, but by design.”³⁶² He asserts that fire departments recognized a void in emergency care and a need for, “all-hazard response organizations.”³⁶³ This void prompted a need for fire firefighters to obtain specialized training, such as “hazardous materials incidents, technical rescues, and human caused and natural disasters.”³⁶⁴ Compton states, “In the modern fire department, 80% of the current emergency calls are responses to EMS incidents.”³⁶⁵

This shift away from fighting fires is occurring not just in the United States. Some fire departments in the United Kingdom have also been embracing the EMS role, by spending more time in community centers teaching “fire prevention, recreation and basic medical care.”³⁶⁶ According to Tom Wieczorek, Director of the International City/County Management Association Center for Public Safety Management, “the change is rather

³⁵⁹ National Fire Protection Association, “Data, Research, and Tools.”

³⁶⁰ McChesney, “Fewer Fires.”

³⁶¹ Dennis Compton, “Communicating Your Value Can Define the Future: How to Defend Your Fire Department from Biased Attacks,” *Firehouse Magazine* 38, no. 12 (December 1, 2013): 26–27, <https://www.firehouse.com/leadership/article/11196948/politics-and-the-fire-service>.

³⁶² Compton, 26.

³⁶³ Compton, 26.

³⁶⁴ Compton, 26.

³⁶⁵ Compton, 26.

³⁶⁶ Chris Kardish, “Fire Departments Shift Their Focus to Medical Care,” *Governing*, April 2014, <http://www.governing.com/topics/public-justice-safety/gov-fire-departments-shift-focus.html>.

than having companies waiting for the alarm bell, they're doing inspections, classes and getting out into the community." They are being proactive. He equates the shift in the fire department's focus to what police were doing years ago in their communities.³⁶⁷ Structure fires have decreased over the years, but similar to the police traffic stop, the threat of a fire cannot be completely eliminated, and thus, fire firefighters will always be needed. Fire departments recognized that new and advanced technology would limit the number of structural fires, so they identified a void in emergency care and pivoted to become "all-hazard response organizations."³⁶⁸

Fire departments have pivoted and refocused their employees' roles in a way that provides more value to their stakeholders and the communities they serve, while still maintaining their core mission of saving lives. Law enforcement agencies must heed the lessons learned from fire departments and recognize what new advantages and challenges APV technology will create for the law enforcement officer. It appears from the research that the APV will create several new opportunities for law enforcement officers to achieve, yet they must be cautious of the potential drawbacks as well. They must also recognize a potential void for law enforcement officers to fill when the APV is rolled out. Fire departments recognized that fewer fires resulted due to technological advancements and identified a void in EMS incidents. The technologically advanced APV may create a void in other areas of law enforcement for officers to pursue. This void may only present itself once the APV is in service and fully functional; thus, law enforcement agencies should be mindful of this possible void to pivot and be successful in the future.

While APV technology will present many regulatory, legal, and ethical challenges for companies, lawmakers, and law enforcement agencies, this thesis does not discuss these concerns in great detail. In addition, this thesis does not recommend a draft policy or specific legislation for the implementation of APV technology. Law enforcement agencies will need to work with automobile manufacturers as well as lawmakers to

³⁶⁷ Kardish.

³⁶⁸ Compton, "Communicating Your Value Can Define the Future."

implement policies specific to each agency and legislation specific to each state. These would be additional areas that will require further research.

B. CONCLUSION

From the invention of the electrical telegraph system to the cellular phone, or from the first electronic calculator to ubiquitous computing, technology has touched almost everything, and do not assume that this situation will change in the near future. A human driver drove the first automobile in 1886, and 91 years later, the first truly AV was unveiled. The advancement of this automotive technology means it will be only a few short years before AVs become commonplace on U.S. roads and freeways. The AVs may potentially impact hundreds of organizations in the private sector, but they will also impact several organizations in the public sector, such as law enforcement agencies. The APV is one way for law enforcement agencies to leverage AV technology.

The APV is a technological advanced platform that incorporates wireless sensor networks, such as thermal imagers, ALPRs, facial recognition, air sampling sensors, and gunshot detection systems. The APV has the potential to impact law enforcement officers by making their jobs both safer and more efficient; but not however, without some unintended consequences for law enforcement agencies to consider. These unintended consequences may be a reduced law enforcement workforce that has enhanced IT skills, but a reduced practical skillset. While not possibly a specific issue for some, law enforcement agencies should be aware of these factors to mitigate any potential concerns. By not understanding these factors, it could be detrimental for law enforcement agencies implementing the APV. Research has shown that other public organizations, such as fire departments, have adapted to new technologies in their field by identifying a void that needs to be filled. The APV will ultimately have a significant impact on law enforcement agencies with endless opportunities while at the same time reducing the risk to its officers, therefore, this thesis recommends that law enforcement agencies should find a void to fill when the APV becomes realized. This void may only present itself once the APV is in service and fully functional; thus, law enforcement agencies should be mindful of this possible void in order to pivot for sustained future success.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

- Accenture. “Reimagining the Police Workforce: Future Vision.” September 26, 2018. <https://www.accenture.com/us-en/insights/public-service/reimagining-police-workforce-future-vision>.
- Ahmed, Mohamed, Harpreetsingh Banvait, Alexandru Mihai Gurchian, and Francois Charette. Autonomous police vehicle, U.S. Patent Application, filed July 12, 2016. <http://www.freepatentsonline.com/20180018869.pdf>.
- Akyildiz, Ian F., Tommaso Melodia, and Kaushik R. Chowdhury. “Wireless Multimedia Sensor Networks: Applications and Testbeds.” In *Proceedings of the IEEE* 96, no. 10 (October 2008): 1588–1605. <https://doi.org/10.1109/JPROC.2008.928756>.
- Anderson, James M., Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and Tobi A. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. Santa Monica, CA: RAND, 2014.
- Anonymous. “Threat Stats.” *SC Magazine; New York* 26, no. 3 (March 2015): 1–26.
- Armerding, Taylor. “The 16 Biggest Data Breaches of the 21st Century.” CSO Online, October 11, 2017. <https://www.csoononline.com/article/2130877/data-breach/the-16-biggest-data-breaches-of-the-21st-century.html>.
- Associated Press. “A Look at Attacks Where Vehicles Have Been Used as Weapons.” *Chicago Tribune*, October 31, 2017. <http://www.chicagotribune.com/news/nationworld/ct-vehicles-as-weapons-20171031-story.html>.
- Auslander, Julie Sue. “Adapt or Die, The Enduring Rule of Innovation.” *Fast Company*, January 23, 2012. <https://www.fastcompany.com/1810048/adapt-or-die-enduring-rule-innovation>.
- Autoweek. “Is This Motorola Autonomous Police Car Patent the Real Robocop of Our Dystopian Future?” October 8, 2018. <https://autoweek.com/article/autonomous-cars/future-law-enforcement-motorola-patents-autonomous-police-car-0>.
- Avalos, George. “Police Use New Technologies to Fight Crime.” *Government Technology*, January 18, 2016. <http://www.govtech.com/dc/articles/Police-Use-New-Technologies-to-Fight-Crime.html>.
- Baev, Valery M., Torsten J. Latz, and Peter E. Toschek. “Laser Intracavity Absorption Spectroscopy.” *Applied Physics B* 69, no. 3 (September 1, 1999): 171–202. <https://doi.org/10.1007/s003400050793>.

- Bennett, Brian. "Beneath the Surface." *Officer*, September 16, 2016. <https://www.officer.com/investigations/article/12232472/are-thermal-cameras-the-next-step-in-law-enforcement-documentation-of-assault-injuries>.
- Bertoncello, Michele, and Dominik Wee. "Ten Ways Autonomous Driving Could Redefine the Automotive World." McKinsey. Accessed January 14, 2019. <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world>.
- Bhuiyan, Johana. "After Two Million Miles, Google's Robot Car Now Drives Better than a 16-Year-Old." *Recode*, October 5, 2016. <https://www.recode.net/2016/10/5/13167364/google-self-driving-cars-2-million-miles>.
- Bigelow, Pete. "Google's Robotaxis Are up and Running as of Today." *AdAge*, December 5, 2018. <https://adage.com/article/cmo-strategy/waymo-s-commercial-driving-service-launches-today/315881/>.
- Bisbee, Terry L., and Daniel A. Pritchard. "Today's Thermal Imaging Systems: Background and Applications for Civilian Law Enforcement and Military Force Protection." In *Proceedings IEEE 31st Annual 1997 International Carnahan Conference on Security Technology*, 202–8. Canberra, ACT, Australia, Australia, 1997. <https://doi.org/10.1109/CCST.1997.626270>.
- Blue Lights Digital. "REFORM—A Digital Response." September 15, 2017. <https://bluelightsdigital.com/reform-review/>.
- Bolkcom, Christopher. *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*. CRS Report No. RS21698. Washington DC: Congressional Research Service, 2004.
- Booth, Michael. "Virginia Supreme Court Takes Aim at Random License Plate Scans by Police." *National Law Journal*, May 4, 2018. <https://www.law.com/nationallawjournal/2018/05/04/virginia-supreme-court-takes-aim-at-random-license-plate-scans-by-police/>.
- Breul, Nick, and Mike Keith. *Deadly Calls and Fatal Encounters: Analysis of U.S. Law Enforcement Line of Duty Deaths When Officers Responded to Dispatched Calls for Service and Conducted Enforcement (2010–2014)*. Washington, DC: Department of Justice, 2015. <https://www.hsdl.org/?abstract&did=794863>.
- Bureau of Justice Statistics. "Cybercrime." Last revised February 1, 2019. <https://www.bjs.gov/index.cfm?ty=tp&tid=41>.
- Bureau of Labor Statistics. "Police and Detectives: Occupational Outlook Handbook." Last modified February 15, 2019. <https://www.bls.gov/ooh/protective-service/police-and-detectives.htm>.

- California Legislative Information. "SB 962, Senate Bill—Introduced by Senator Leno." Accessed November 16, 2017. http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_0951-1000/sb_962_bill_20140206_introduced.htm.
- Center for Sustainable Systems, University of Michigan. "Autonomous Vehicles Factsheet." August 2018. <http://css.umich.edu/factsheets/autonomous-vehicles-factsheet>.
- Center on Privacy & Technology at Georgetown Law. "The Perpetual Line-Up." October 18, 2016. <https://www.perpetuallineup.org/>.
- Centers for Disease Control and Prevention. "Motor Vehicle Crash Injuries." October 7, 2014. <https://www.cdc.gov/vitalsigns/crash-injuries/index.html>.
- Chang, Lulu. "New Sensor System Detects Gunshots, Can Automatically Lock down a School." *Digital Trends*, April 3, 2018. <https://www.digitaltrends.com/cool-tech/sensor-detects-gunshots/>.
- Chavez, Nicole, Holly Yan, Eric Levenson, and Steve Almasy. "New York Attack: Suspect Charged with Terrorism Offenses." CNN, November 1, 2017. <http://www.cnn.com/2017/11/01/us/new-york-attack/index.html>.
- Chestnut, Wesley D. "Fire Truck of the Future." Fire Apparatus Manufacturers' Association, April 4, 2017. <https://www.fireapparatusmagazine.com/articles/print/volume-22/issue-4/departments/fama-forum/fire-truck-of-the-future.html>.
- Choi, Kyung-Shick, Mitch Librett, and Taylor J. Collins. "2014 Gunshot Detection." Research Gate, July 29, 2016. https://www.researchgate.net/publication/305720016_2014_Gunshot_Detection.
- City of Chicago. "Technology." Accessed October 14, 2018. <https://www.cityofchicago.org/city/en/depts/oem/provdrs/tech.html>.
- Clinton, Paul. "Hidden Drugs in Vehicle 'Traps.'" *POLICE Magazine*, July 6, 2010. <http://www.policemag.com/channel/gangs/articles/2010/07/hiding-drugs-in-vehicle-traps.aspx>.
- Compton, Dennis. "Communicating Your Value Can Define the Future: How to Defend Your Fire Department from Biased Attacks." *Firehouse Magazine* 38, no. 12 (December 1, 2013): 26–27. <https://www.firehouse.com/leadership/article/11196948/politics-and-the-fire-service>.
- Counter Extremism Project. "Vehicles as Weapons of Terror." May 22, 2017. <https://www.counterextremism.com/vehicles-as-weapons-of-terror>.

- Cowper, Thomas J., and Bernard H. Levin. "Autonomous Vehicles: How Will They Challenge Law Enforcement?" FBI Law Enforcement Bulletin, February 13, 2018. <https://leb.fbi.gov/articles/featured-articles/autonomous-vehicles-how-will-they-challenge-law-enforcement>.
- Cui, Shumo, Benjamin Seibold, Raphael Stern, and Daniel B. Work. "Stabilizing Traffic Flow via a Single Autonomous Vehicle: Possibilities and Limitations." In *IV 2017—28th IEEE Intelligent Vehicles Symposium* (2017): 1336–41. <https://doi.org/10.1109/IVS.2017.7995897>.
- Cuomo, Governor Andrew M. "Governor Cuomo Announces Major Facial Recognition Technology Milestone with 21,000 Fraud Cases Investigated." August 21, 2017. <https://www.governor.ny.gov/news/governor-cuomo-announces-major-facial-recognition-technology-milestone-21000-fraud-cases>.
- Customs and Border Protection. "CBP to Test the Operational Use of Small Unmanned Aircraft Systems in 3 U.S. Border Patrol Sectors." Press release, September 14, 2017. <https://www.cbp.gov/newsroom/national-media-release/cbp-test-operational-use-small-unmanned-aircraft-systems-3-us-border>.
- Davies, Alex. "The Wired Guide to Self-Driving Cars." Wired, December 13, 2018. <https://www.wired.com/story/guide-self-driving-cars/>.
- Deloitte United States. "Deloitte Study: Consumer Trust in Autonomous Vehicles on the Rise." Accessed September 3, 2018. <https://www2.deloitte.com/us/en/pages/about-deloitte/articles/press-releases/2018-global-automotive-consumer-survey-press-release.html>.
- Denmon, Christian. "How Self Driving Cars Impact Traffic Law Enforcement." Denmon Pearlman, July 4, 2017. <https://denmon.lawyer/criminal-law/self-driving-cars/>.
- Department of Homeland Security. "Snapshot: S&T and HSI Collaborate on Technologies to Save Children from Abuse and Exploitation." March 6, 2018. <https://www.dhs.gov/science-and-technology/news/2018/03/06/snapshot-st-and-hsi-collaborate-technologies-save-children>.
- Department of Justice. "Drug Movement into and within the United States." February 2010. <https://www.justice.gov/archive/ndic/pubs38/38661/movement.htm#Flow>.
- Douglas, Dave. "Night Vision and Thermal Imaging." March 27, 2012. <http://www.policemag.com/channel/technology/articles/2012/03/owning-the-night.aspx>.
- Douglas, Theo. "Report: As Tech Changes Law Enforcement, Its Workforce Must Adapt." Government Technology, October 16, 2018. <http://www.govtech.com/public-safety/Report-As-Tech-Changes-Law-Enforcement-Its-Workforce-Must-Adapt.html>.

- du Preez, Derek. "Police Watchdog—'Forces Not Keeping Pace with Technology.'" Diginomica Government, March 3, 2017. <https://government.diginomica.com/2017/03/03/police-watchdog-forces-not-keeping-pace-technology/>.
- Du, Shan, Mahmoud Ibrahim, Mohamed Shehata, and Wael Badawy. "Automatic License Plate Recognition (ALPR): A State-of-the-Art Review." In *IEEE Transactions on Circuits and Systems for Video Technology* 23, no. 2 (February 2013): 311–25. <https://doi.org/10.1109/TCSVT.2012.2203741>.
- Duffer, Robert. "The Shift Is on: Manual Transmissions May Be Endangered but They're Also Beloved." *Chicago Tribune*, July 11, 2018. <https://www.chicagotribune.com/classified/automotive/sc-auto-cover-manual-transmissions-20180710-story.html>.
- Durbin, Dee-Ann. "Fatal Tesla Crash Could Slow Automakers' Race toward Driverless Cars." *Portland Press Herald*, July 1, 2016. <https://www.pressherald.com/2016/07/01/fatal-tesla-crash-could-slow-automakers-momentum-toward-driverless-cars/>.
- ECI. "The Ambulance of the Future." *Homeland Security* (blog). October 2, 2017. <https://medium.com/homeland-security/the-ambulance-of-the-future-264bb32c9e6e>.
- Eisenstein, Paul A. "Self-Driving Cars Take to the Road, but Not Everyone Is Ready to Ride." CNBC, October 14, 2018. <https://www.cnbc.com/2018/10/14/self-driving-cars-take-to-the-road-but-not-everyone-is-ready-to-ride.html>.
- Elmaghraby, Adel S., and Michael M. Losavio. "Cyber Security Challenges in Smart Cities: Safety, Security and Privacy." *Journal of Advanced Research* 5, no. 4 (July 31, 2014): 491–97.
- Ericson, Lars, Jon Hayes, Chad Huffman, Jack Fuller, and Vince Libonati. "Through-the-Wall Sensors (TTWS) for Law Enforcement: Use Case Scenarios (Version 1.3)." National Criminal Justice Reference Service, 1–24. April 24, 2014. <https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=268796>.
- Evarts, Eric C. "Why Are Manual Transmissions Disappearing?" *U.S. News & World Report* (blog). September 27, 2016. <https://cars.usnews.com/cars-trucks/best-cars-blog/2016/09/why-are-manual-transmissions-disappearing>.
- Fagnant, Daniel J., and Kara Kockelman. "Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations." *Transportation Research Part A-Policy and Practice* 77 (July 2015): 167–81. <https://doi.org/10.1016/j.tra.2015.04.003>.
- Federal Bureau of Investigation. "Uniform Crime Reporting (UCR) Program." Accessed June 5, 2018. <https://www.fbi.gov/services/cjis/ucr>.

- Ferris, David D., Robert W. McMillan, Nicholas C. Currie, Michael C. Wicks, and Mohamed-Adel Slamani. "Sensors for Military Special Operations and Law Enforcement Applications." In *Proceedings of SPIE*, vol. 3062 (June 20, 1997): 173–180. <https://doi.org/10.1117/12.276674>.
- Finkelstein, Robert, and Rob Davis. *Autonomous Cars for Law Enforcement*. Washington, DC: Police Foundation, Potomac, MD: Robotic Technology Inc., 2017. <https://www.techcastglobal.com/wp-content/uploads/ckfinder/userfiles/files/White%20Paper%20Mod%201%20Autonomous%20Cars%20Law%20Enforcement%202%20March%2017.pdf>.
- Finn, Rachel L., and David Wright. "Unmanned Aircraft Systems: Surveillance, Ethics and Privacy in Civil Applications." *Computer Law & Security Review* 28, no. 2 (April 1, 2012): 184–94. <https://doi.org/10.1016/j.clsr.2012.01.005>.
- FLIR Systems. "Thermal Imaging, Night Vision and Infrared Camera Systems." Accessed September 10, 2018. <https://www.flir.com/>.
- Fridman, Lex. "Tesla Autopilot Miles." *MIT Human-Centered AI* (blog). Last Updated January 3, 2019. <https://hcai.mit.edu/tesla-autopilot-miles/>.
- Fussell, Sidney. "Schools Are Spending Millions on High-Tech Surveillance of Kids." *Gizmodo*, March 16, 2018. <https://gizmodo.com/schools-are-spending-millions-on-high-tech-surveillance-1823811050>.
- Gettinger, Dan. "Public Safety Drones." Center for the Study of the Drone, April 2017. <http://dronecenter.bard.edu/public-safety-drones/>.
- . "Public Safety Drones: An Update." *Center for the Study of the Drone* (blog). May 28, 2018. <https://dronecenter.bard.edu/public-safety-drones-update/>.
- Global Health Observatory, World Health Organization. "Registered Vehicles Data by Country." Last Updated November 30, 2015. <http://apps.who.int/gho/data/node.main.A995>.
- Government Accountability Office. *Border Security: Additional Actions Needed to Strengthen Collection of Unmanned Aerial Systems and Aerostats Data*. GAO-17-152. Washington, DC: Government Accountability Office, 2017. <https://www.gao.gov/products/GAO-17-152>.
- . *Community Policing Grants: COPS Grants Were a Modest Contributor to Declines in Crime in the 1990s*. GAO-06-104. Washington, DC: Government Accountability Office, 2005. <https://www.gao.gov/products/GAO-06-104>.
- . *FACE Recognition Technology: FBI Should Better Ensure Privacy and Accuracy*. GAO-16-267. Washington, DC: Government Accountability Office, 2016. <https://www.gao.gov/products/GAO-16-267>.

- Gulf Business. "Dubai Aims to Remove Police Officers from Streets." (Blog). March 13, 2018. <https://gulfbusiness.com/dubai-aims-remove-police-officers-from-streets/>.
- Haddal, Chad C., and Jeremiah Gertler. *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*. CRS Report No. RS21698. Washington, DC: Congressional Research Service, 2010. <http://www.dtic.mil/docs/citations/ADA524297>.
- Harris, Mark. "FBI Warns Driverless Cars Could Be Used as 'Lethal Weapons.'" *The Guardian*, July 16, 2014, sec. Technology. <http://www.theguardian.com/technology/2014/jul/16/google-fbi-driverless-cars-lethal-weapons-autonomous>.
- Harvey, Brad. "Top 10 Uses for Thermal Imaging in Law Enforcement." *Tactical Response Magazine*, June 2006. <https://www.bullard.com/press-release/11/top-10-uses-for-thermal-imaging-in-law-enforcement>.
- Hayes, Jon, and Lars Ericson. "Through-the-Wall Sensors for Law Enforcement: Best Practices." Google, March 2014. <https://www.google.com/search?client=safari&rls=en&q=Through-the-Wall+Sensors+for+Law+Enforcement:+Best+Practices&ie=UTF-8&oe=UTF-8>.
- Hollyfield, Amy. "Smartphone Theft down in San Francisco." ABC7 San Francisco, July 28, 2017. <http://abc7news.com/2257099/>.
- Hollywood, John S., Dulani Woods, Andrew Lauland, Brian A. Jackson, and Richard Silberglitt. *Emerging Technology Trends and Their Impact on Criminal Justice*. Santa Monica, CA: RAND, 2018. https://www.rand.org/pubs/research_briefs/RB9996.html.
- Hollywood, John S., Dulani Woods, Richard Silberglitt, and Brian A. Jackson. *Using Future Internet Technologies to Strengthen Criminal Justice*. Santa Monica, CA: RAND, 2015.
- Horwitz, Sari, Ellen Nakashima, and Matea Gold. "DHS Tells States about Russian Hacking during 2016 Election." *Washington Post*, September 22, 2017. https://www.washingtonpost.com/world/national-security/dhs-tells-states-about-russian-hacking-during-2016-election/2017/09/22/fd263a2c-9fe2-11e7-8ea1-ed975285475e_story.html?utm_term=.fc551a19fb9b.
- Hottentot, Chris, Veronique Meines, and Mike Pinckaers. *Experiments on Autonomous and Automated Driving: An Overview 2015*. The Hague, Netherlands: ANWB, 2015. https://www.anwb.nl/binaries/content/assets/anwb/pdf/over-anwb/persdienst/rapport_inventarisatie_zelfrijdende_auto.pdf.

- Huet, Ellen. "As California Kill-Switch Law Takes Effect, Smartphone Theft Already Down 32%." *Forbes*, July 1, 2015. <https://www.forbes.com/sites/ellenhuet/2015/07/01/as-california-kill-switch-laws-takes-effect-smartphone-theft-already-down-32/>.
- Hyland, Shelley. "Full-Time Employees in Law Enforcement Agencies, 1997–2016." Bureau of Justice Statistics, August 28, 2018. <https://www.bjs.gov/index.cfm?ty=pbdetail&iid=6366>.
- Ibrahim, Yahya. "The Ultimate Mowing Machine." *Inspire Magazine* 2 (2010): 53–54.
- Iozzio, Corinne. "Lasers Could Detect Drunk Drivers on the Road." *Smithsonian*, July 1, 2014. <https://www.smithsonianmag.com/innovation/Lasers-Could-Detect-Drunk-Drivers-On-The-Road-180951903/>.
- Jackman, Tom. "Who Wants to Be a Police Officer? Job Applications Plummet at Most U.S. Departments." *Washington Post*, December 4, 2018. https://www.washingtonpost.com/crime-law/2018/12/04/who-wants-be-police-officer-job-applications-plummet-most-us-departments/?noredirect=on&utm_term=.02b31e872677.
- Jeacock, Matt. "How Cops and Hackers Could Abuse California's New Phone Kill-Switch Law." *WIRED*, August 26, 2014. <https://www.wired.com/2014/08/how-cops-and-hackers-could-abuse-californias-new-phone-kill-switch-law/>.
- Joe, Benjamin. "Ford Developing Autonomous Systems for Police Cars, Other Emergency Vehicles." *IPWatchdog*, April 7, 2018. <http://www.ipwatchdog.com/2018/04/07/ford-developing-autonomous-systems-police-cars-emergency-vehicles/id=95218/>.
- Kaan, Jens. *User Acceptance of Autonomous Vehicles*. Delft, Netherlands: Delft University of Technology, 2017.
- Kardish, Chris. "Fire Departments Shift Their Focus to Medical Care." *Governing*, April 2014. <http://www.governing.com/topics/public-justice-safety/gov-fire-departments-shift-focus.html>.
- Khalid, Asma. "Facial Recognition May Boost Airport Security but Raises Privacy Worries." *NPR*, June 26, 2017. <https://www.npr.org/sections/alltechconsidered/2017/06/26/534131967/facial-recognition-may-boost-airport-security-but-raises-privacy-worries>.
- Khosrow-Pour, Mehdi. *Dictionary of Information Science and Technology*. 2nd ed. Hershey, PA: IGI Global, 2012.
- Kitchin, Rob. *Getting Smarter about Smart Cities: Improving Data Privacy and Data Security*. Dublin, Ireland: Data Protection Unit, Department of the Taoiseach, 2016.

- Lee, Kristen. "It's True: Self-Driving Cars Will Make Our Driving Skills Even Worse." *Jalopnik*, August 10, 2017. <https://jalopnik.com/its-true-self-driving-cars-will-make-our-driving-skill-1797709144>.
- Levinson-Waldman, Rachel. "Hiding in Plain Sight: A Fourth Amendment Framework for Analyzing Government Surveillance in Public." Emory University School of Law. Accessed September 10, 2018. <http://law.emory.edu/elj/content/volume-66/issue-3/articles/hiding-plain-fourth-amendment-government-surveillance-public.html>.
- Mangino, Matthew T. "Matthew T. Mangino: Facial Recognition Technology and the Expectation of Privacy." *Providence Journal*, July 27, 2018. <https://www.providencejournal.com/opinion/20180727/matthew-t-mangino-facial-recognition-technology-and-expectation-of-privacy>.
- Marron, Alex, Anthony J. Suppelsa, and Barbara R. Doutre, Mobile law enforcement communication system and method, United States US10049419B1, filed September 6, 2017, and issued August 14, 2018. <https://patents.google.com/patent/US10049419B1/en?q=10049419>.
- Mazerolle, Lorraine Green, Cory Watkins, Dennis Rogan, and James Frank. "Using Gunshot Detection Systems in Police Departments: The Impact on Police Response Times and Officer Workloads." *SAGE Journals* 1, no. 2 (June 1, 1998): 21–49. http://journals.sagepub.com/doi/abs/10.1177/109861119800100202?casa_token=MJr-dlwgKz8AAAAA:05_SseJRZkbJHmYr72qU6FPY613O3v_11oOKAtbz42T93UPiKxZi9zhU-LpPWX0Jymt0AH_N9QLWpA.
- McChesney, Fred S. "Fewer Fires, so Why Are There Far More Firefighters?" *Washington Post*, September 4, 2015. https://www.washingtonpost.com/opinions/2015/09/04/05316abe-517c-11e5-933e-7d06c647a395_story.html?utm_term=.491be99e2504.
- Młyńczak, Jarosław, Jan Kubicki, and Krzysztof Kopczyński. "Stand-off Detection of Alcohol in Car Cabins." *Journal of Applied Remote Sensing* 8, no. 1 (May 19, 2014): 083627-1–083627-7. <https://doi.org/10.1117/1.JRS.8.083627>.
- Morgan, Steve. "Top 5 Cybersecurity Facts, Figures and Statistics for 2017." CSO Online, October 19, 2017. <https://www.csoonline.com/article/3153707/security/top-5-cybersecurity-facts-figures-and-statistics-for-2017.html>.
- Mosquet, Xavier, Thomas Dauner, Nikolaus Lang, Michael Rüßmann, Antonella Meipochtler, Rakshita Agrawal, and Florian Schmieg. "Revolution in the Driver's Seat: The Road to Autonomous Vehicles." Boston Consulting Group, April 21, 2015. <https://www.bcg.com/publications/2015/automotive-consumer-insight-revolution-drivers-seat-road-autonomous-vehicles.aspx>.

- National Fire Protection Association. "Data, Research, and Tools." Accessed October 5, 2017. <http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics>.
- National Highway Traffic Safety Administration. "Automated Driving Systems." August 2018. <https://www.nhtsa.gov/vehicle-manufacturers/automated-driving-systems>.
- National Institute of Justice. "Through-the-Wall Surveillance." Last modified January 23, 2015. <https://www.nij.gov:443/topics/technology/detection-surveillance/enhanced-surveillance/pages/through-wall.aspx>.
- National Law Enforcement Officers Memorial Fund. "Causes of Line of Duty Deaths, Over the Past Decade (2008–2017)." Updated March 15, 2018. <https://nleomf.org/facts-figures/causes-of-law-enforcement-deaths>.
- Naughton, Keith. "Robots Are Ruining Your Driving Skills." August 10, 2017, Bloomberg. <https://www.bloomberg.com/news/articles/2017-08-10/as-robots-take-the-wheel-driving-skills-begin-to-hit-the-skids>.
- Netherlands Foreign Investment Agency. "How the Dutch Drive Mobility." May 24, 2018. <https://investinholland.com/how-the-dutch-drive-mobility/>.
- . "KPMG Ranks the Netherlands No 1 in Autonomous Vehicles Readiness." January 17, 2018. <https://investinholland.com/kpmg-ranks-the-netherlands-no-1-in-autonomous-vehicles-readiness/>.
- Newman, Lily Hay. "The Biggest Cybersecurity Disasters of 2017 So Far." WIRED, July 1, 2017. <https://www.wired.com/story/2017-biggest-hacks-so-far/>.
- Neyfakh, Leon. "Plenty of Firefighters, but Where Are the Fires?" *Boston Globe*, September 7, 2013. <https://www.bostonglobe.com/ideas/2013/09/07/plenty-firefighters-but-where-are-fires/isCPriPauX078UKHdixu0K/story.html>.
- NHTSA. "Automated Vehicles for Safety." Accessed September 28, 2017. <https://www.nhtsa.gov/technology-innovation/automated-vehicles>.
- Officer Down Memorial Page. "Honoring Officers Killed in 2018." 2018. <https://www.odmp.org/search/year/2018>.
- Page, Tom. "Self-Driving Police Patrol to Hit Dubai." CNN, June 30, 2017. <http://www.cnn.com/style/article/dubai-police-self-driving-vehicle-o-r3/index.html>.
- Pamplin Media Group. "Ask A Cop: How Much Mileage Is Put on a Police Car?" December 25, 2014. <https://pamplinmedia.com/lor/48-news/244840-112074-ask-a-cop-how-much-mileage-is-put-on-a-police-car>.

- Parmar, Divyarajsinh N., and Brijesh B. Mehta. "Face Recognition Methods & Applications." Cornell University. March 3, 2014. <http://arxiv.org/abs/1403.0485>.
- PC Magazine Encyclopedia. "Autonomous Vehicle Definition." Accessed September 28, 2017. <https://www.pcmag.com/encyclopedia/term/57132/autonomous-vehicle>.
- Peters, Michael A. "Technological Unemployment: Educating for the Fourth Industrial Revolution." *Educational Philosophy and Theory* 49, no. 1 (January 2, 2017): 1–6. <https://doi.org/10.1080/00131857.2016.1177412>.
- Police Executive Research Forum. *Building Interdisciplinary Partnerships to Prevent Violent Extremism*. Washington, DC: Office of Community Oriented Policing Services, 2017.
- PoliceOne. "Police Are in Hot Pursuit of Driving Skills." May 3, 2002. <https://www.policeone.com/archive/articles/51319-Police-are-in-Hot-Pursuit-of-Driving-Skills/>.
- PoliceOne Staff. "Police Job Applications Decrease at Most U.S. Departments." December 6, 2018. <https://www.policeone.com/recruitment-retention-crisis/articles/482289006-Police-job-applications-decrease-at-most-U-S-departments/>.
- Poon, Linda. "How Police Are Preparing for the Arrival of Autonomous Cars." City Lab, October 25, 2017. <https://www.citylab.com/transportation/2017/10/waymo-police-first-responders-emergency-vehicles-driverless-cars/543351/>.
- Post Regulatory Commission. *Annual Compliance Determination Report—Fiscal Year 2015*. Washington, DC: Post Regulatory Commission, 2016.
- Prudente, Tim, and Sarah Meehan. "Baltimore's New Gunshot Detection System Hears Four Shootings in First Night." *The Baltimore Sun*, June 1, 2018. <http://www.baltimoresun.com/news/maryland/crime/bs-md-ci-shotspotter-20180601-story.html>.
- Puthuparampil, Jojo. "Dubai, Say Hello to These New Self-Driving Police Vehicles." *Inc. Arabia* (blog). June 29, 2017. <http://www.incarabia.com/technology/dubai-say-hello-to-these-new-self-driving-police-vehicles/>.
- Quiceno, Grace, Claudia Álvarez, Raúl Ávila, Óscar Fernández, Carlos Jaime Franco, Martin Kunc, and Isaac Dynner. "Scenario Analysis for Strategy Design: A Case Study of the Colombian Electricity Industry." *Energy Strategy Reviews* 23 (January 1, 2019): 57–68. <https://doi.org/10.1016/j.esr.2018.12.009>.
- Reaves, Brian A. "Police Vehicle Pursuits, 2012–2013." Bureau of Justice Statistics, May 9, 2017. <https://www.bjs.gov/index.cfm?ty=pbdetail&iid=5906>.

- Rector, Ralph. "The Facts about COPS: A Performance Overview of the Community Oriented Policing Services Program." The Heritage Foundation, September 25, 2000. <https://www.heritage.org/crime-and-justice/report/the-facts-about-cops-performance-overview-the-community-oriented-policing>.
- Ries, Eric. *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. New York: Crown Business, 2011.
- Riley, Michael, and Jordan Roberston. "Russian Cyber Hacks on U.S. Electoral System Far Wider than Previously Known." Bloomberg, June 13, 2017. <https://www.bloomberg.com/news/articles/2017-06-13/russian-breach-of-39-states-threatens-future-u-s-elections>.
- River Logic. "Scenario Analysis: A Powerful Analytics Force." *River Logic* (blog). April 8, 2016. <https://blog.riverlogic.com/scenario-analysis-a-powerful-analytics-force>.
- Roberts, David J., and Meghann Casanova. "Automated License Plate Recognition (ALPR) Use by Law Enforcement: Policy and Operational Guide, Summary." 1–14. TRID, August 2012. <https://trid.trb.org/view/1223373>.
- Rockwell, Mark. "DHS Seeks Drones to Patrol the Border." Federal Computer Week, May 2, 2018. <https://fcw.com/articles/2018/05/02/dhs-border-drones.aspx>.
- Roufa, Timothy. "Learn How Today's Technology Will Transform Tomorrow's Police." The Balance Careers. Updated December 1, 2018. <https://www.thebalancecareers.com/technologies-that-are-changing-the-way-police-do-business-974549>.
- Royakkers, Lambèr, and Rinie van Est. "A Literature Review on New Robotics: Automation from Love to War." *International Journal of Social Robotics* 7, no. 5 (November 1, 2015): 549–70. <https://doi.org/10.1007/s12369-015-0295-x>.
- Rudolph, Gert, and Uwe Voelzke. "Three Sensor Types Drive Autonomous Vehicles." *Sensors Magazine*, November 10, 2017. <https://www.sensorsmag.com/components/three-sensor-types-drive-autonomous-vehicles>.
- Safety Team. "How Safe Are Self-Driving Cars?" Safer America, November 7, 2016. <http://safer-america.com/safe-self-driving-cars/>.
- Saleh, Khalid. "How Much of the World Population Is Online—Statistics and Trends." *Invesp* (blog). Accessed January 15, 2019. <https://www.invespro.com/blog/world-population-online/>.
- Seewer, John. "Law Enforcement Agencies Turning to Drones to Fight Crime." PoliceOne, May 29, 2018. <https://www.policeone.com/police-products/Police-Drones/articles/475612006-Law-enforcement-agencies-turning-to-drones-to-fight-crime/>.

- Simon Alvarez. "Netherlands Ranks 1st in Autonomous Vehicle Readiness, U.S. Places 3rd." *TESLARATI* (blog). January 25, 2018. <https://www.teslarati.com/netherlands-ranks-1st-autonomous-vehicle-readiness-kpmg-study/>.
- Sisson, Patrick. "How Will Driverless Cars Change Street Policing?" *Curbed*, February 10, 2017. <https://www.curbed.com/2017/2/10/14581254/cops-law-enforcement-driverless-cars-autonomous-vehicles>.
- Skogan, Wesley. *What Happened to Community Policing?* Washington, DC: Community Oriented Policing Services, n.d. Accessed June 18, 2018. https://cops.usdoj.gov/pdf/taskforce/submissions/Skogan_Wesley_Testimony.pdf.
- Staff Writer. "DEA-Led Operation Delivers More Than 2,000 Arrests." *POLICE Magazine*, June 10, 2010. <http://www.policemag.com/channel/gangs/news/2010/06/10/dea-led-operation-delivers-over-2-000-arrests.aspx>.
- Statistic Brain Research Institute. "Driving Citation Statistics." Accessed September 29, 2017. <http://www.statisticbrain.com/driving-citation-statistics/>.
- Strom, Kevin J. *Research on the Impact of Technology on Policing Strategy in the 21st Century: Final Report*. Rockville, MD: Office of Justice Programs' National Criminal Justice Reference Service, 2016.
- Tech Policy Lab. *Driverless Seattle; How Cities Can Plan for Automated Vehicles*. Seattle, WA: University of Washington, 2017. http://www.mobility-innovation-center.uwcomotion-sites.com/wp-content/uploads/2017/02/TPL_Driverless-Seattle_2017.pdf.
- Thompson, Cadie. "New Details about the Fatal Tesla Autopilot Crash Reveal the Driver's Last Minutes." *Business Insider*, June 20, 2017. <https://www.businessinsider.com/details-about-the-fatal-tesla-autopilot-accident-released-2017-6>.
- . "Why Driverless Cars Will Be Safer than Human Drivers." *Business Insider*, November 16, 2016. <http://www.businessinsider.com/why-driverless-cars-will-be-safer-than-human-drivers-2016-11>.
- Threlfall, Richard. "2018 Autonomous Vehicles Readiness Index." KPMG, April 13, 2018. <https://home.kpmg.com/xx/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html>.
- Tokson, Matthew. "Knowledge and Fourth Amendment Privacy." *Northwestern University Law Review* 111, no. 1 (December 15, 2016): 139–204.
- Transportation Research Board. "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey." Accessed October 13, 2018. <http://www.trb.org/Main/Blurbs/172209.aspx>.

- United States Post Office. "First-Class Mail Volume since 1926." March 2018. <https://about.usps.com/who-we-are/postal-history/first-class-mail-since-1926.htm>.
- University of Baltimore Law Review Staff. "Facial Recognition Technology: First and Fourth Amendment Implications." *University of Baltimore Law Review* (blog). April 14, 2017. <https://ubaltlawreview.com/2017/04/14/facial-recognition-technology-first-and-fourth-amendment-implications/>.
- Vanderbilt, Tom. "Autonomous Cars through the Ages." WIRED, February 6, 2012. <https://www.wired.com/2012/02/autonomous-vehicle-history/>.
- Vincent, James. "Police in Dubai Have Recruited a Self-Driving Robo-Car that Can 'Scan for Undesirables.'" The Verge, June 29, 2017. <https://www.theverge.com/2017/6/29/15893802/dubai-police-robot-drone-car>.
- Virmani, Deepali, Ankita Soni, Shringarica Chandel, and Manas Hemrajani. "Routing Attacks in Wireless Sensor Networks: A Survey." Cornell University, 1–8. May 29, 2014. <http://arxiv.org/abs/1407.3987>.
- Walton, Jennifer, Mark Spellman, and Joseph Crabtree. *Evaluation of Thermal Imaging Technology for Commercial Vehicle Screening*. Lexington, KY: University of Kentucky, Kentucky Transportation Center, 2015. <http://dx.doi.org/10.13023/KTC.RR.2015.19>.
- Watts, Adam C., Vincent G. Ambrosia, and Everett A. Hinkley. "Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use." *Remote Sensing* 4, no. 6 (June 8, 2012): 1671–92. <https://doi.org/10.3390/rs4061671>.
- Waymo. "On the Road." Accessed October 17, 2017. <https://waymo.com/ontheroad/>.
- Weiss, Jim. "Facial Recognition Technology in Law Enforcement." Hendon Publishing Company. Accessed September 5, 2018. http://www.hendonpub.com/resources/article_archive/results/details?id=4291.
- Weiss, Jonathon. "UAVs in Law Enforcement." JonnyUAV, February 7, 2018. <https://www.jonnyuav.com/single-post/2018/01/24/UAVs-in-Law-Enforcement>.
- Welch, David, and Elisabeth Behrmann. "Who's Winning the Self-Driving Car Race?" May 7, 2018, Bloomberg. <https://www.bloomberg.com/news/features/2018-05-07/who-s-winning-the-self-driving-car-race>.
- Wolfe, Aristotle. "Unstoppable? The Gap between Public Safety and Traffic Safety in the Age of Driverless Cars." Master's thesis, Naval Postgraduate School, 2017.

Wolfendale, Jessica. "The Moral Questions in the Debate on What Constitutes Terrorism." *The Conversation*, December 11, 2017. <http://theconversation.com/the-moral-questions-in-the-debate-on-what-constitutes-terrorism-86990>.

Woody, Christopher. "Fake Vegetables, Frozen Sharks, and an Xbox—Here Are Some of Drugs Smugglers' Most Bizarre Methods." *Business Insider*, April 2, 2017. <http://www.businessinsider.com/drug-smugglers-methods-hiding-places-2017-4>.

World Technology Network. "The World Summit on Technological Unemployment." April 24, 2015. <https://www.wtn.net/technological-unemployment-summit>.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California