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The use of autonomous systems in emergency medical services: bridging human intelligence and technology

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THESIS

THE USE OF AUTONOMOUS SYSTEMS IN EMERGENCY MEDICAL SERVICES: BRIDGING HUMAN INTELLIGENCE AND TECHNOLOGY

by

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December 2015

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The rapid development of autonomous systems (AS), which are technological systems or processes that either support or replace human decision making, will have a significant impact on emergency medical services (EMS). EMS provider organizations must be prepared to not only interact with AS by having response protocols in place that provide responders with guidance in dealing with these systems during an emergency, but they must also be able to leverage this technology to improve the quality of public safety services. Effective leveraging of AS technologies will enable emergency medical responders to improve efficiency, reduce cost, and provide greater service to those in need.

The strengths, weaknesses, opportunities, and threats evaluation of the impact of not embracing AS reveals that weakness in efficiency and safety and threats from the emerging technology-based markets and the users of EMS will be high, that the number of opportunities to improve required emergency response and deliver expedient medical care will be diminished, and that strengths may be nonexistent.

The thesis focuses on the analysis of what AS are, how they are used in the provision of EMS today, how they may be leveraged in EMS systems in the future, and which concerns are related to the use of these systems with regard to homeland security.

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THE USE OF AUTONOMOUS SYSTEMS IN EMERGENCY MEDICAL SERVICES: BRIDGING HUMAN INTELLIGENCE AND TECHNOLOGY

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF ACRONYMS AND ABBREVIATIONS

ACA	Patient Protection and Affordable Care Act
AQ	Al Qaeda
AS	autonomous systems
AV	autonomous vehicle
AVL	automatic vehicle location
AVT	autonomous vehicle technology
C2C	car-to-car
CAD	computer aided dispatch
CHP	California Highway Patrol
DSRC	dedicated short-range communication
EMS	emergency medical services
GPS	global positioning systems
IR	infrared
IoT	Internet of Things
LIDAR	light detection and ranging
PII	personally identifiable information
POS	point of sale
RF	radio frequency
RVD	remote vehicle disruption
SWOT	strengths, weaknesses, opportunities, and threats
V2I	vehicle-to-infrastructure
V2V	vehicle-to-vehicle

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I. INTRODUCTION

The "flying ambulance" was first described by Dominique-Jean Larrey in 1792 as a technological means to improve care for injured battlefield soldiers in Napoleon's Army.[1] Larrey, a French surgeon, determined that more causalities could be saved if they could be removed from the battlefield quickly and then provided with surgical medical care. In addition, the army would be able to remain robust if the number of fatal causalities was reduced, thereby maintaining a large fighting force. Combined with the human skill of conducting medical triage, which is the sorting of injuries by criticality, the ambulance would quickly enable the wounded to be transported from the battlefield to treatment areas or from treatment areas to hospitals.

Ambulances were designed to meet the needs of the mission and to augment the services provided by the medical practitioners of the time. Some ambulances were lightweight and could be more easily maneuvered on the battlefield to quickly transport patients to safer areas where medical care could occur, while other ambulances were constructed on more sturdy carriages and could carry more patients at one time to travel longer distances. The advancement of ambulance technology continued through the American Civil War (1861–1865) and greatly expanded with the use of helicopter ambulances known as "medevac's"[2] during the Vietnam War (1965–1975). The addition of this technology increased patient survivability and provided greater access to critically wounded personnel operating in remote and hostile combat zones.

As technology improved, ambulances continued to evolve in ways that would make them more valuable to human users. The means by which the carriage was powered evolved from humans, to horses, to motorized engines. The carriage itself benefited from enhancements that made it lighter, more comfortable for the patient and the caregiver,

[1] American College of Emergency Physicians, "The Revolutionary Flying Ambulance of Napoleon's Surgeon," accessed May 29, 2015, http://www.acep.org/About-Us/The-Revolutionary-Flying-Ambulance-of-Napoleon-s-Surgeon/.

[2] Medevac is the emergency removal of sick or injured people from an area especially by helicopter. Merriam-Webster, "Medevac," accessed June 5, 2015, http://www.merriam-webster.com/dictionary/medevac.

safer, and ergonomic design attributes assisted users in accessing supplies with greater ease and efficiency. Modern ambulances today are equipped with electronic navigational aids, video cameras, high-end medical devices that communicate with other devices wirelessly, encrypted voice and data transmission systems, and numerous automated systems. In the next decade, new technologies will change the way emergency medical services (EMS) are provided much in the same fashion that the innovative Napoleonic "flying ambulance" did 1792. The ambulance of tomorrow will bridge responders human intellectual processing with artificial intelligence that supports or even replaces human decision making through the use of autonomous systems (AS).

A. PROBLEM

The rapid development of AS, which are technological systems or processes that either support or replace human decision making, will have a significant impact on public safety services, including EMS. EMS provider organizations must be ready to not only interact with AS by having response protocols in place that provide responders with guidance in dealing with these systems during an emergency, but they must be able to leverage this technology to improve the quality of public safety services. It is likely that the leveraging of AS technologies will enable emergency medical responders to improve efficiency, reduce cost, and provide greater service to those in need.

This thesis will provide an overview of what AS are, the ways that they are currently used in EMS, how they will be used in the future, homeland security considerations, and a summary that provides recommendations for EMS providers. The research is intended to make the reader aware of technology that will change the way EMS operate in the next several decades; understanding the anticipated changes is critical for strategic planning and operational policy development.

In the following chapters, the primary research question "Can autonomous system capabilities be integrated into a 9-1-1 EMS system to improve efficiency and safety, and thereby provide a better level of service for the patient and responder?" will be considered as information is provided as to the fundamentals of AS, near range applications, more distant applications, homeland defense considerations, and finally, a conclusion that summarizes the findings.

B. AUTONOMOUS SYSTEMS

AS are present in our lives every day, from sensors in kitchen refrigerators that send performance data to the manufacturer, to global positioning systems (GPS) that aid drivers in finding their way to destinations, to self-driving cars. No longer just a science fiction possibility for the future or service for the elite for a price, these technologies now touch most people, including those responsible for providing and receiving EMS.

Most AS systems to date have been either been largely invisible or easily understood by the user; the cruise control function in a car is a prime example. However, most people are not likely to understand or be interested in the depth and degree to which they actually interact with these systems and what is happening "behind the scenes." For example, most EMS responders are aware of "On Star," GPS systems that send medical data electronically, and various call-demand software systems. However, most responders are passive customers of these systems, rather than active agents who integrate information from AS systems in an effort to improve operational practices.

One of the most important types of AS are AVTs, which experts believe will dramatically change the nature of transportation in the near future. EMS organizations will fail to protect their populations and themselves if they do not identify methods to address the emerging increase in AVTs. Emergency medical organizations must be able to successfully navigate emerging AVTs to leverage human resources, increase safety, and harden the organization from homeland security threats that may be exploited by either criminal and or terrorist organizations if ineffectively integrated or monitored. Tangible benefits include a decrease in human resource needs, realization of greater operational efficiencies, and decreased injuries or death of public safety responders and civilians.

The scope of the study is limited to EMS providers within the United States and excludes other emergency responders including fire service and law enforcement. This thesis will not examine the specific technical aspects of the technologies, which are often proprietary, but rather it will focus on the human interaction with AS capabilities.

The provision of EMS is managed very differently across the United States, ranging from all volunteer to highly paid public safety personnel. Although the methods by which these systems operate differ greatly, core components are identical and will be influenced by autonomous technologies (i.e., every EMS agency responds to emergencies, requires incident addresses, needs maps, sends data, cares for people, etc.). Each of these core components is influenced by AS, and therefore, will be impacted by the progress in technology.

C. EMERGENCY MEDICAL SERVICES IN THE UNITED STATES

The modern era of EMS in the United States began in 1966 with the publication of the paper *Accidental Death and Disability: The Neglected Disease of Modern Society* by the National Academy of Sciences.[3] The report described the lack of comprehensive standards and integration within the delivery of EMS. This "white paper" became the cornerstone for the growth of EMS systems for the next 30 years. In 1996, the National Highway and Traffic Safety Administration released in the *Emergency Medical Services Agenda for Future* (Agenda), which expanded on the principles contained in white paper and organized EMS provision into 14 attributes. These attributes, identified in Figure 1, were designed to ensure that EMS remained the public's emergency medical safety net.[4]

[3] National Academy of Sciences, *Accidental Death and Disability: The Neglected Disease of Modern Society* (Washington, DC: National Academy of Sciences, 1966), http://www.ems.gov/pdf/1997-reproduction-accidentaldeathdissability.pdf.

[4] National Highway and Traffic Safety Administration, *Emergency Medical Services Agenda for the Future* (Washington, DC: National Highway and Traffic Safety Administration, 1996), http://www.nhtsa.gov/people/injury/ems/agenda/emsman.html.

Figure 1. Emergency Medical Services Agenda for the Future Attributes

1.	Integration of Health Services
2.	EMS Research
3.	Legislation and Regulation
4.	System Finance
5.	Human Resources
6.	Medical Direction
7.	Education Systems
8.	Public Education
9.	Prevention
10.	Public Access
11.	Communication Systems
12.	Clinical Care
13.	Information Systems
14.	Evaluation

Source: "Emergency Medical Services Agenda for the Future," 1996, http://www.nhtsa.gov/people/injury/ems/agenda/emsman.html.

Technology has been a key to realizing the improvements that are identified in the Agenda. The use of non-human resources and technological tools in the area of health services integration, medical direction, public access, prevention, communication, clinical care, and information systems have modernized EMS exponentially in the past 18 years. EMS professionals now rely on artificial intelligence data or systems on every emergency medical response to help make informed medical care decisions.

The Patient Protection and Affordable Care Act (ACA) was adopted into law in 2010.[5] The ACA will have significant impacts on the provision of EMS, most of which remain unknown today. The mandate that all Americans have health care coverage means that EMS systems will have to work more efficiently and effectively to meet increased demands while reducing unnecessary costs. Technological solutions will be required to assist EMS professionals in not only providing quality EMS but by leveraging methods to do them in new ways including increased reliance on AS.

[5] United States Department of Health and Human Services, *The Patient Protection and Affordable Care Act* (Washington, DC: United States Department of Health and Human Services, 2010), http://www.hhs.gov/healthcare/rights/index.html.

D. NEXUS TO HOMELAND SECURITY AND DEFENSE

As the use of technology increases, the potential for exploitation of data becomes a homeland security concern as bad actors attempt to use AS to intentionally disrupt or corrupt critical systems. A simple example is the ability for systems to be "hacked," such as the ability to disable or activate AS. The majority of literature reviewed focuses on highly integrated data collection and analysis that results in the performance of an AV system, either as an aide or replacement for human action. Corruption of these systems can lead to not only isolated failures of critical systems, such as dispatching, automated routing, and transmission of patient data but could result in a cascade of increasing and synergistic failures.

Leading experts in the field of AS have suggested that the use of AS will benefit most business processes, including EMS. Little research exists that disputes these claims, as many AS have become a transparent component of a bigger operation, such as the use of AS in the airline industry has made commercial airline travel safer and more efficient. However, some AS made have caused human users to become overly reliant on technology and less capable as human operators or to use these technologies in nefarious ways. An example may be the reliance on automatic flight control systems, which caused the crash of Air France Flight 447 when the pilots failed to solve the problem effectively when automated instrumentation failed.[6] The March 24, 2015 crash of a Germanwings passenger aircraft provides another example of how AS can be corrupted when the pilot intentionally used automated systems to auger the aircraft into the ground, killing all on board.[7] Systems designed to provide assistance to human operators or intended to serve as "fail safe" or redundant safety systems may be repurposed to cause catastrophic failures by those wishing create terror.

Interoperable systems used by first responders represent a high-risk opportunity for those wishing to attack public safety systems. The corruption of these systems can

[6] Air France, "Information of the Crash of Air France Flight #447," accessed June 4, 2015, http://www.airfrance447.com/.

[7] CNN, "Germanwings Plan Crash: What We Know So Far," April 25, 2015, http://www.cnn.com/2015/03/30/europe/france-germanwings-plane-crash-what-we-know/

lead to catastrophic consequences, such as using EMS vehicles and their systems as weapons of opportunity. The thesis will explore the risks of use of each of the technology pieces discussed, the benefits, and make recommendations that are mindful of opportunities for misuse with system engineering in mind.

E. UNDERSTANDING THE APPLICATION OF AUTONOMOUS SYSTEMS

EMS providers are currently required to interact with autonomous technologies but the impact is small and the consequences of not embracing the technology are inconsequential at this time in history. As the technology becomes more pervasive, AS will not be able to be ignored and may change the way services are provided regardless of the desires of the EMS industry. The external business applications and potential for efficiencies will drive changes in EMS; therefore, EMS leaders must be aware of the advances and strive to apply these technologies to public safety practices. In addition, EMS officials are responsible for understanding the threats, opportunities, and vulnerabilities that exist to provide appropriate services to those they are responsible for protecting and to include them in standard operating procedures, contingency plans, and emergency operations plans.

Understanding the effects of AS will help EMS service providers in understanding what AS is and is not, how it influences the industry, areas of recognized risk, areas of potential benefit, and be able to provide illustrations that can be shared and used locally to develop policies and procedures that will benefit various constituent groups including responders, elected and appointed officials, business leaders, and the citizenry.

This thesis provides an easy to follow set of practical recommendations that can be implemented immediately, others will provide the framework for short-term consideration, and others will be of a visionary nature. A summary of the technology provides the reader with a basic overview of AS including known timelines for next implementations, such as car-to-car (C2C) communications by 2016 and integration of

AVs with the “built environment,” which is defined as human integration with cities, structures, systems, technology, roadways, etc.[8]

It is likely that many within the EMS profession believe automatic cars and other AS systems are far in the distant future. Simply calling attention to AS that are in practice today and those that have a set timeline for implementation will increase awareness within the EMS profession. Many EMS officials consider themselves aware of current technology and believe that the type of advancements that are truly around the corner are distant possibilities rather than today’s reality. The degree of background information and the recommendations that will be provided in the thesis will provide a framework for EMS agencies to better understand AS and to be able to take steps towards policy and procedure development.

In the following chapters, the primary research question “Can autonomous system capabilities be integrated into a 9-1-1 EMS system to improve efficiency and safety, and thereby provide a better level of service for the patient and responder?” is explored. A review of available literature is provided in Chapter II. Chapter III provides the reader with an overview of what AS are by focusing on the use of AS primarily related to vehicles, the systems that support automated vehicles, or those systems that are associated with vehicles. Understanding the core components of these systems will enable the reader to understand what is in place today and the roadmap for advancement into the future. Chapter IV then explores specific AS in place today and commonly used by EMS providers. Many readers may be unaware that these systems are components of autonomous technologies or that they are currently available on the consumer market. Chapter V applies the roadmap to the progression of autonomous technologies that will be realized within EMS systems in coming next decades. This chapter brings together the understanding of what systems can do and how they will benefit EMS in the area of efficiency and safety improvements. The increased use of technologies within the provision of essential public safety services creates a concern for homeland security. Chapter VI evaluates these concerns, primary by distinguishing between intentional and

[8] University of Windsor, “What Does the Term “Built Environment Mean,” accessed June 7, 2015, http://www1.uwindsor.ca/vabe/built-environment.

non-intentional disruption of systems. The interconnected networks of technology provide an opportunity for small failures to be exponentially damaging as any one system has a direct implication to a connected or associated "system of systems." The failure of an individual piece of the network can result in catastrophic failures resulting in the failure of EMS operations. Finally, Chapter VII provides an overview of the research that has been presented, identifies recommendations for EMS providers, and provides the results of the analysis that has been conducted throughout the thesis.

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II. LITERATURE REVIEW

The use of AV systems in the provision of EMS is a new concept related to the use of technology in the homeland defense environment. Available and emerging advances in technology will likely enable EMS to transform many routine and supportive tasks into partially or fully automated platforms that will assist human resources in improving the quality, speed, and scope of services provided.

Extensive literature exists in regard to the technological aspects of AVTs. As an emerging technology, information may quickly be replaced with a next generation approach or may be dismissed based on the expedient growth of the sophistication of the technology. Literature has been reviewed from a variety of sources including trade journals, peer and academic articles, government reports, and industry best-practice documents. However, literature specific to automated vehicle use in EMS is fairly limited. It is likely related to the fast pace of technology and the practice of vehicle manufactures leading the providers of EMS into purchasing choices only at the time a purchase is needed. Meaning, only when provided with options during a new vehicle purchase may most EMS organizations be made aware of current ASTs as presented by vendors seeking to make a higher price sale. Proprietary information is not freely shared nor is marketing of AS a key focal space in trade conferences, publications, and practices within the EMS industry at this time.

In review of the literature used to frame this thesis, basic informational data is used to provide a foundation for the reader in understanding what AV systems are, how they generally operate, and how the systems integrate with EMS. Reviewed literature then focuses on current applications of AS, future uses, and finally implications to homeland security.

A good starting point for understanding automated systems is the 2014 publication by RAND entitled *Autonomous Vehicle Technology, A Guide for*

Policymakers.[9] This report provides an excellent summary of core issues and the state of art technology related to AVs. As a cornerstone document for understanding the various aspects of autonomous technologies, this report provides various natural jumping-off points for further investigation throughout this literature review.

In *Google's Autonomous Car Applies Lessons Learned from Driverless Races* by Alan Brown, the literature provides the reader with a basic understanding of how the technology works that is easily understandable and intentionally is non-technical.[10] It is critical that the reader be able to understand the core components of automated vehicles to understand how the technology may apply to current options. The information presented by Brown is simple and paints an easy to understand concept of operations for AVs. Understanding that most people have experienced air travel or have a basic knowledge of what air travel includes, Robert Goyer's, "Cars and Airplanes: Automation Dilemmas" illuminates the value of having automated systems as a redundancy and back-up system to human operators.[11] In his publication, Goyer discusses the value of an automatic pilot system that can not only provide data to the pilot, such as horizon information, make advisory notices, or actually take over flight controls if needed. Nicholas D. Cottrell et al. have discussed factors related to stress while driving and how AS in "The Role of Automation in Reducing Stress and Negative Affect While Driving" are able to reduce unnecessary stress through the replacement of human observations with automatic data collection and analysis that provides guidance to vehicle operators.[12] Brown, Goyer, and Cottrell provide information that can be easily adopted into EMS operations that make the provision of emergency services safer for not only the vehicle operator but to the people driving on the streets that encounter emergency vehicles by enabling the vehicle operator to focus on critical tasks rather than routine driving skills.

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[9] James M. Anderson, Nidhi Kalra, and Karlyn D. Stanley, *Autonomous Vehicle Technology: A Guide for Policymakers* (Santa Monica, CA: RAND Corporation, 2014).

[10] Alan S. Brown, "Google's Autonomous Car Applies Lessons Learned from Driverless Races," *Mechanical Engineering* 133, no. 2 (February 2011): 31.

[11] Robert Goyer, "Cars and Airplanes: Automation Dilemmas," *Flying* 141, no. 5 (May 2014): 12.

[12] Nicholas D. Cottrell and Benjamin K. Barton, "The Role of Automation in Reducing Stress and Negative Affect while Driving," *Theoretical Issues in Ergonomics Science* 14, no. 1 (2013): 53–68.

In “Integrating Automobile Multiple Intelligent Warning Systems: Performance and Policy Implications,” Angela Wei Ling Ho provides a perspective that assists EMS providers in understanding considerations related to AS.[13] The information presented by Ho frames considerations that may be adapted to use within EMS organizations as related to the use in emergency vehicles, such as ambulances and other emergency response vehicles, similar to those in passenger automobiles. Emergency response vehicles contain a great deal of independent warning systems from internal and external cameras, patient care data peripherals, call-prediction software, proximity sensors, etc. Ho explains the value of integration of these multiple systems to improve the quality of intelligence that may be integrated into AS applications.

Naranjo et al., and Panagao et al., describe the processing of dual mode operations and how relative factors are considered and processed resulting in an autonomous action.[14] This information is beneficial in understanding how the technology “thinks” compared to human brain processing. The collaboration of humans and artificial intelligence is core in its application to emergency and public safety response; technology must augment the decisions made by human actors. Therefore, understanding the “back and forth” data communication process is important.

Understanding how AS interact with humans is a key to understanding not only the technology but also how AVs will cooperate in task completion. Technology use must augment or replace human initiated activities for it to provide a return on investment. Understanding the interaction between humans and technology is important for not only safety, but for acceptance within the EMS industry. Jeffery S. Wit in “Vector Pursuit Path Tracking for Autonomous Ground Vehicles” goes further in explaining the requirements

[13] Angela Wei Ling Ho, “Integrating Automobile Multiple Intelligent Warning Systems: Performance and Policy Implications, (master’s thesis, Massachusetts Institute of Technology, Engineering Systems Division, Technology and Policy Program, 2006).

[14] José E. Naranjo et al., “Interoperable Control Architecture for Cybercars and Dual-Mode Cars,” *IEEE Transactions on Intelligent*, 10, no. 1 (March 2009): 146–154; José E. Naranjo, Carlos Gonzalez, Ricardo García, and Teresa de Pedro, “Lane-Change Fuzzy Control in Autonomous Vehicles for the Overtaking Maneuver,” *IEEE Transactions on Intelligent Transportation Systems* 9, no. 3 (2008): 438–450; Dimitra Panagou and Vijay Kumar, “Cooperative Visibility Maintenance for Leader-Follower Formations in Obstacle Environments,” *IEEE Transactions on Robotics* 30, no. 4 (August 2014): 831.

of greater infrastructure that is necessary for AV use.[15] Not only do AVs need to be able to avoid obstacles, they must have the ability to determine an avoidance path that permits the vehicle to continue through a navigated virtual roadway beyond the hazard and yet come close enough to the desired location without compromising safety or efficiency as is required of emergency vehicles.

Simizu and Poggio in "Direction Estimation of Pedestrian from Images" identify how technology systems will sense pedestrians so that AVs may avoid dangerous interaction.[16] Understanding how an AV will avoid a pedestrian is valuable, understanding how an emergency vehicle will interact with multiple "pedestrians" on or near the scene of an emergency is essential. Often a "pedestrian" is the reason for an emergency response; therefore, the system must have overrides in case it is necessary for emergency vehicles to break proximity rules (such as driving on sidewalks). In 2013, the Panasonic Corporation conducted research related to the use of radar waves in vehicles to detect obstructions, such as pedestrians and other vehicles; this literature provides examples of how current technology can be implemented into emergency vehicles to improve safety during response and to bystanders.[17]

A number of authors have described how AS can be used specifically in emergency medical response operations. Theodore Chan et al., for example, discuss how technology can be used during times of disaster when routine roadways and access points may be limited due to debris, civil disobedience, or loss of infrastructure.[18] In such cases, AVTs have the capability to leverage real-time geospatial mapping to direct responders to areas in need of service. The routing of personnel, supplies, or evacuation of the ill or injured could be managed through the use of unmanned vehicles to address obstacles,

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[15] Jeffrey S. Wit, "Vector Pursuit Path Tracking for Autonomous Ground Vehicles," *Star* 45, no. 19 (2007).

[16] Hiroaki Shimizu and Tomaso Poggio, "Direction Estimation of Pedestrian from Images," *Star* 45, no. 3 (2007).

[17] Panasonic Corporation, *Panasonic Advances Automotive Millimeter-Wave Radar Technology to Detect Pedestrians and Vehicles in Low Visibility Conditions*. Osaka, Japan: Panasonic Corporation, 2013.

[18] Theodore C.-Chan et al., "Information Technology and Emergency Medical Care during Disasters," *Academic Emergency Medicine* 11, no. 11 (November 2004): 1229–36.

such as those presented by Clancy et al., in "New Jersey's EMS Response to Superstorm Sandy: A Case Study of the Emergency Management Assistance Compact."[19]

Experts, such as Thomas E. Lampert, in his article, "New and Fringe Residential Development and Emergency Medical Services Response Times in the United States," argues that day-to-day improvements in reducing EMS response times will benefit from the use of autonomous technologies.[20] Specifically, C2C communications will assist by feeding real-time road congestion information. Collision impact data can be routed to dispatch centers so that the most appropriate emergency response personnel are sent to the scene. Geographic fencing data may be used to identify suspect terrorist activity related to critical infrastructure, and patient transport time to the hospital may be reduced by automated routed to the closet hospital (by time) by considering traffic patterns, road construction, etc.

The use of AS can decrease the incidents of emergency vehicle collisions through the integration of the technologies discussed as expressed by Custalow and Gravitz in "Emergency Medical Vehicle Collisions and Potential for Preventative Intervention."[21] Motor vehicle collision avoidance is a cornerstone of AVTs; however, the application to emergency vehicles is even more important. Emergency vehicles travel to emergency scenes a high rates of speed, bypass routine "rules of the road," and often travel in groups (more than one emergency vehicle responding to a single location).

As EMS moves to embrace modern technologies, a shift from traditional radio communications systems will occur that will lead to better integration of systems than had been identified in "The NHTSA Emergency Medical Services Communications

[19] Terry Clancy, Kenneth Christensen, and Henry P. Cortacans, "New Jersey's EMS Response to Superstorm Sandy: A Case Study of the Emergency Management Assistance Compact," *Prehospital and Disaster Medicine* 29, no. 3 (June 2014): 326–9.

[20] Thomas E. Lambert and Peter B. Meyer, "New and Fringe Residential Development and Emergency Medical Services Response Times in the United States," *State and Local Government Review* 40, no. 2 (2008): 115–124.

[21] Catherine B. Custalow and Craig S. Gravitz, "Emergency Medical Vehicle Collisions and Potential for Preventive Intervention," *Prehospital Emergency Care* 8, no. 2 (April–June 2004): 175–184.

Program" by Glass.[22] The shift from the use of commonplace technology, such as radios, to newer and more integrated systems, will enable users to collect exponential data that may be harvested and then displayed through various other mediums as a method of increasing situational awareness.

Using the literature presented, more sophisticated integration will be discussed within the thesis related to available EMS operations. These examples will include the dispatch of supply vehicles without human operators to support emergency incident scenes with equipment and restock, automated movement of patients from the scene of injury to a medical care facility without a human driver, or possibility medical care attendant, accessing hostile environments, such as active shooter and hazardous materials situations with vehicles that can permit victims to self-evacuate without risk to humans, and real time fail-safe support to human interactions, such as nonemergency vehicles pulling to the right and stopping to permit emergency vehicles to pass safety or making vehicles automatically divert around a traffic collision that has just occurred.

As the use of technology increases, the potential for the exploitation of data becomes a greater concern. User identification and security systems are a component of the technologies that must be considered. Biometric software applications offer the ability to secure systems, increase accountability and tracking of users, and increase efficiency.[23]

Some forms of technology will enable EMS providers to use existing base knowledge that is then augmented by intelligence systems, such as portable and hands-free devices to assist in making medical care decisions.[24] The use of such devices enables field providers to consult in real-time with physicians or other specialized providers when the need arises. The linkage between the AV itself and various peripherals is critical to

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[22] Christopher J. Glass, "The NHTSA Emergency Medical Services Communications Program," *IEEE Transactions on Vehicular Technology* 28, no. 4 (1979): 243–248.

[23] PR Newswire, "Tulsa's Emergency Medical Services Authority Selects BioconX Software and Sony Biometric Devices to Protect Computer Security," January 15, 2002, 1.

[24] John Epler and Gary Zimmer, "Intelligent Medical Systems for Aerospace Emergency Medical Services," *STAR* 42, no. 2 (2004): 1–6.

making the use of intelligence systems beneficial. The network of systems must be complementary and technically integrated in a method similar to C2C technologies.

C2C communication, known as “connected vehicles,” is the ability for autonomous cars to communicate with each other and an engineered environment that serves as the communication hub to permit AS functionality. The Joint Program Office, a U.S. Department of Transportation agency, publishes a wide range of literature that focuses on intelligent transportation systems including connected vehicles.[25] Information published by the Joint Programs Office provides a broad and high-level literature source that will be used to assist in explaining the core components of connected vehicle technologies. Dedicated short-range communication (DSRC) is a component that electronically sends messages from a source, such as a roadway warning system, to a vehicle so that the on-board driver information system will be alerted to hazards ahead.[26] This type of communication can alert drivers or even possibly cause vehicles to pull to the side to permit emergency vehicles to pass safety or keep accident scenes safe from vehicles operated by unaware drivers.

Homeland security concerns related to the use of AS focus on intentional disruption or corruption of data. A simple example is the ability for systems to be “hacked,” such as the ability to disable AS, such as those described by Kevin Poulsen where he details the disabling of over 100 cards remotely in the magazine *Wired*.[27] The majority of literature reviewed focuses on highly integrated data collection and analysis that results in the performance of an AV system, either as an aide or replacement for human action.

Leading experts in the field of AS have suggested that the use of AS will benefit most business processes, including EMS. Little research exists that disputes these claims, as many AS have become a transparent component of a bigger operation, such as the use

[25] Intelligent Transportation Systems, Joint Program Office, *Connected Vehicle Research* (Washington, DC: United States Department of Transportation, 2013).

[26] Clemson University Vehicular Electronics Laboratory, “Dedicated Short Range Communications,” accessed August 23, 2015, http://www.cvel.clemson.edu/auto/systems/dsrc.html.

[27] Kevin Poulsen, “Hacker Disables More than 100 Cars Remotely,” *Wired*, March 17, 2010.

of AS in the airline industry has made commercial airline travel safer and more efficient. However, some autonomous AS made have caused human users to become overly reliant on technology and less capable as human operators or to use these technologies in nefarious ways. An example may be the reliance on automatic flight control systems, which caused the crash of Air France Flight 447 when one of the pilots failed to solve the problem effectively when automated instrumentation failed, or the most recent crash of a German passenger flight when the pilot used automated systems to auger the aircraft into the ground, intentionally killing all on board.

Interoperable systems used by first responders represent a high-risk opportunity for those wishing to attack public safety systems. The corruption of these systems can lead to catastrophic consequences, such as using EMS vehicles and their systems as weapons of opportunity. The thesis will explore the risks of use of each of the technology pieces discussed, the benefits, and make recommendations that are mindful of opportunities for misuse with system engineering in mind as discussed by Khalid and Banks in “Systems Engineering Approach to First Responder Operability.”[28]

In review of available literature, adequate information exists that describes the technology currently available, and in the future, specific applications that will aid EMS providers in enhancing the safety and efficiency, and key examples of the ability for nefarious actors to cause disruption to these systems.

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[28] Adeel Khalid and Scott C. Banks, “Systems Engineering Approach to First Responder Interoperability,” *American Society for Engineering Education* (2011): 00734–00716.

III. BACKGROUND OF AUTONOMOUS SYSTEMS

AS are technological systems or processes that either support or replace human decision making. In the modern world, the speed by which technology improves is exponential and has never progressed so quickly compared to any other time in history. In particular, advancements related to the leveraging of Internet access through wired or wireless connections have increased the transmission of information, improved efficiencies, and enabled business practices to be streamlined to save money and time while increasing safety and efficiency. This thesis focuses on the use of AS primarily related to AVs, the systems that support automated vehicles, or those systems that are associated with vehicles.

The cruise control on a passenger vehicle is the easiest example of an AS that most people have experienced first-hand. The cruise control system automatically changes engine power and applies the vehicle brakes to maintain a set vehicle speed as determined by the driver. The use of the cruise control systems help the driver conserve fuel, which results in cost savings by minimizing fluctuations in fuel consumption. The driver holds the responsibility to establish the most appropriate speed, determines when the cruise control will be active, manually activates turn signals, and maneuvers the vehicle using the steering wheel. In the near future, the AS (cruise control) will know the legal speed limit and then set the vehicle to travel at the designated speed, activate turn signals and the horn when indicated, automatically increase and decrease speed to maneuver around hazards, route to the drivers selected fuel station when needed, and activate other systems to avoid a collision through its close range communications ability with the built environment.

To frame AS into easily understandable categories, the next sections will break AS into the following components: the Internet of Things (IoT), AV technology, and finally, C2C technology. Understanding these three components will assist the reader in navigating how each interacts with one another reliances, and general operation.

A. THE INTERNET OF THINGS

The IoT is the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence.[29] In 2015, the world became aware of an example of the IoT when a Malaysian passenger airliner disappeared from radar screens while on a routine flight. In the days that followed, the world learned that a great many aircraft systems were monitored by remote sensors that send streams of data to a central server using land and satellite-based Internet connections. In the case of the missing airliner, collected data related to engine performance was transmitted to on-ground servers that enabled the aircraft to be tracked.[30] Collected data included altitude, speed, direction, and other engine related performance measures.

Data from various flight controls, engines, comfort systems, radio communication systems, etc., are used by the airline to schedule maintenance, monitor systems, track flights, and other applications to aid in routine management of the airline. These systems may then interconnect so that a maintenance variance trigger (such as an engine performing at levels less than expected by the manufacturer or operator) activates a scheduling program that autonomously coordinates with a supply ordering system to ship a needed part, issue a work order, and reserve space in a maintenance bay located along the intended route of the scheduled aircraft.

Disparate pieces of information are collected and then routed through one or more gateways, which are managed by servers. These servers are then connected through the wireless world through "cloud-based" servers where data may be aggregated and routed to other servers that may be used to analyze data, power user applications on mobile or handheld devices, or simply be deposited into data repositories. According to the National Institutes of Standards and Technology (NIST), cloud-based services have five primary essential components consisting of on-demand self-service, broad network

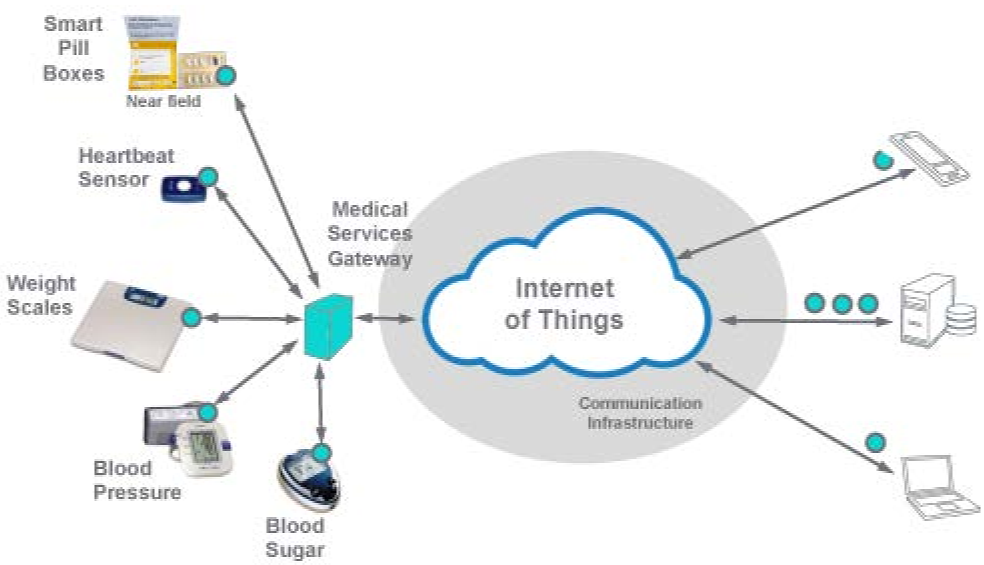
[29] Feng Xia et al., "Internet of Things," *International Journal of Communication Systems* 25, no. 9 (2012): 1101.

[30] John Goglia, "Aircraft Engine Monitoring: How It Works and How It Could Help Malaysia Air 370 Crash Investigators," *Forbes*, March 13, 2014, http://www.forbes.com/sites/johngoglia/2014/03/13/aircraft-engine-monitoring-how-it-works-and-how-it-could-help-malaysia-air-370-crash-investigtors/.

access, resource pooling, rapid elasticity, and measured service.[31] The IoT provides the data necessary to provide the essential services of cloud computing.

In Figure 2, various peripheral medical devices are illustrated showing the two-way communication of data from each other including communication to a server or servers. In this example, if a variance is recognized in a "heartbeat sensor" or abnormal values are registered through a "blood pressure" input, the "medical services gateway" could activate a script that would call the patient, schedule a physician's appointment, or send an order to a local pharmacy to refill a prescription. This level of integration is not meant to replace human intelligence, but to eliminate the tasks that may lead to a patient not remaining compliant with a physician's instructions.

Figure 2. General Example of the Internet of Things



Source: Chris Mayer, "New M2M Portable Project Arrives at Eclipse—Welcome Mihini," jaxenter, July 23, 2012, http://jaxenter.com/new-m2m-portable-project-arrives-at-eclipse-welcome-mihini-104770.html.

The simple example provided in Figure 2 can be greatly expanded to an application within EMS. Figure 3 illustrates a complex network of data sources that can

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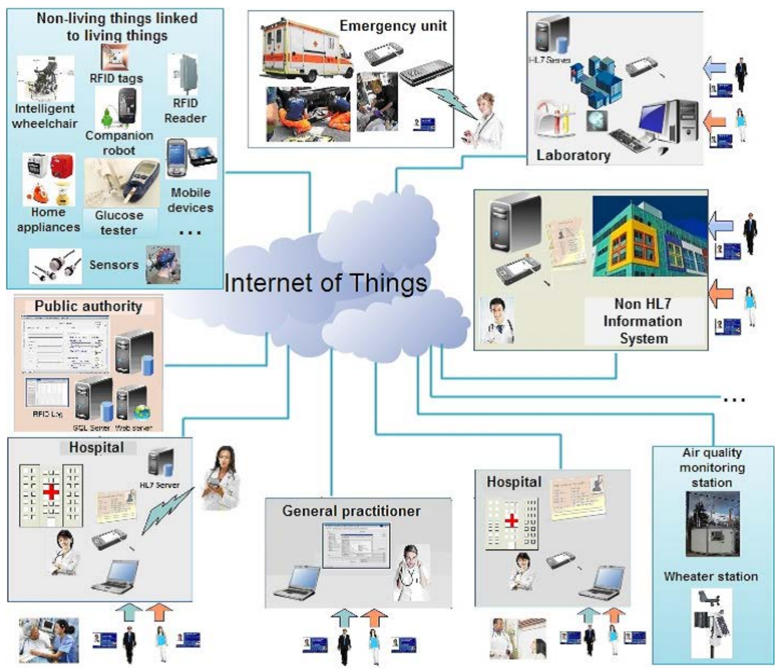
[31] National Institutes of Standards and Technology, *The NIST Definition of Cloud Computing.* (Special Publication 800–145) (Gaithersburg, MD: U.S. Department of Commerce, 2011), http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf.

be used and analyzed to make the provision of EMS services more efficient, safer, and integrated. Using the common medical example provided prevoiusly, the EMS example includes an exponential number of inputs that may be analyzed at various collection points from hospitals, laboratories, medical suppliers, field response units, dispatch centers, partner public-safety agencies, patient medical records, and peripheral medical devices, such as cardiac and vital signs monitors.

Figure 3. Emergency Medical Systems Related Internet of Things



Source: "Internet of Things," March 2014, https://sensormonitoring.files.wordpress.com/2014/03/iot.png.

B. AUTONOMOUS VEHICLE TECHNOLOGY

The "Google Car," "automatic car," "driverless vehicle," and "robot car" are all common terms associated with autonomous vehicle technology (AVT). Generally AVs are designed to assist the human driver with completing various tasks required to operate the vehicle safety and efficiently, to permit the human driver to focus on observing for hazards and steering the vehicle. The ability for a vehicle to drive itself in the near future is real, and such vehicles are likely to be a commonplace sight in the next 10 years. The ability for cars (including other vehicles) to operate without a human driver will change the world by providing access to those who have not been able to travel, operate a vehicle independently, or access services.

The "Google Car" is one of the most recognized examples of AVT. Equipped with various sensors that provide the computer with the human equivalent of seeing, feeling, smelling, and hearing the environment, the car has had an almost spotless safety record on the road during its trial. Google has stated that in the six years that the Google Car has been in testing and has traveled over 1.7 million miles, only 11 accidents have occurred and all were due to human operator error.[32] The ability to test autonomous vehicles on a larger scale is increasing as states implement legislation that will permit autonomous vehicles to travel on the highways of America collecting even more data and operating in a wider variety of situations. The technology that supports AVs continues to mature, which makes vehicle operation safer and smoother. However, the primary weakness appears to be the lack of legislation that enables AVs to be placed into the consumer market.

In 2014, RAND published a report entitled *Autonomous Vehicle Technology, A Guide for Policymakers*.[33] This report provides an excellent summary of core issues and the state of art technology related to AVs. As a cornerstone document for understanding the various aspects of autonomous technologies, this report provides various natural jumping-off points for further investigation into specific aspects of AVTs. The report has received wide spread distribution and is likely responsible for much of the awareness of understanding the policy level considerations required to implement policies successfully that will lead to large-scale acceptance of AVTs in the United States. This report has been used by vehicle manufactures and insurers to assist in their development of new vehicle features that will be not only required in the very near future but in the development of

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[32] M. Silicon Beat Obrien, "Google Self-driving Car Crash Rates: Worrisome or Impressive?," May 11, 2015, http://www.siliconbeat.com/2015/05/11/google-self-driving-car-crash-rates-worrisome-or-impressive/.

[33] Anderson, Nidhi, and Stanley. *Autonomous Vehicle Technology: A Guide for Policymakers*.

"extras" that will attempt to make one vehicle standout over another to command the sales market.[34]

The technology industry is sold on the use and benefits of AVs; however, it is essential that the populous hold an interest and that they will want to be consumers of AVs. In Google's "Autonomous Car Applies Lessons Learned from Driverless Races," Alan Brown provides a basic summary understanding of how the technology works that is easily understandable and intentionally is non-technical.[35] It is critical that the average user be able to understand the core components of automated vehicles to understand how the technology may apply to a potential buyer or user, such as reducing the production of harmful green-house gasses, decreasing the footprint of the built environment, making traffic flow faster and safer, and increasing access for those who do not drive.

The future of development of AVs is not without concern. While the accident rates are currently very low and the number of AV units on the road is minuscule, as the use of AVs expands, it is likely that unforeseen occurrences may cause injuries or death. It is important to understand that cars will not transform from being human operated to non-human operated overnight. Several levels of automation exist from the most basic including cruise control systems and "parking assist" devices to the future days of non-human operated units. The current primary focus and market for AVs is making human operation safer by leveraging automatic technologies to provide real-time and actionable data to the driver. As these technologies progress, the role of the human operator will be diminished as much as is possible.

AVT is designed to make vehicle operation safer. Most people have experienced air travel or at least have basic knowledge of what air travel entails. Robert Goyer illuminates the value of having automated systems as a redundancy and back-up system to human operators.[36] He discusses the value of an automatic pilot system that can not only provide data to the pilot, such as horizon information, make advisory notices, or

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[34] Insurance Information Institute, "Self-Driving Cars and Insurance," February 2015, http://www.iii.org/issue-update/self-driving-cars-and-insurance.

[35] Brown, "Google's Autonomous Car Applies Lessons Learned from Driverless Races," 31.

[36] Goyer, "Cars and Airplanes: Automation Dilemmas," 12.

actually take over flight controls if needed. This system is similar to those being installed in automobiles today, and represents the same benefits to drivers as to pilots. Human stress while driving is another concern of vehicle operators, AV technology is likely able to increase safety by decreasing driver stress through automatic support systems. Nicholas D. Cottrell et al. have discussed factors related to stress while driving and how AS are able to reduce unnecessary stress through the replacement of human observations with automatic data collection and analysis that provides guidance to vehicle operators.[37]

Understanding how AS interact with humans is a key to understanding not only the technology but also how AVs will cooperate in task completion. Technology use must augment or replace human initiated activities for it to provide a return on investment. Understanding the interaction between humans and technology is important for not only safety, but for acceptance within the EMS industry. Jeffery S. Wit goes further in explaining the requirements of greater infrastructure that is necessary for AV use.[38] Not only do AVs need to be able to avoid obstacles, they must have the ability to determine an avoidance path that permits the vehicle to continue through a navigated virtual roadway beyond the hazard and yet come close enough to the desired location without compromising safety or efficiency, as is required of emergency vehicles.

Vehicle interaction with pedestrians is a key element of AV behavior. Simizu and Poggio in "Direction Estimation of Pedestrian from Images" identify how technology systems will sense pedestrians so that AVs may avoid dangerous interactions.[39] Understanding how an AV will avoid a pedestrian is valuable; understanding how an emergency vehicle will interact with multiple "pedestrians" on or near the scene of an emergency is essential. Often a "pedestrian" is the reason for an emergency response; therefore, the system must have overrides in case it is necessary for emergency vehicles to break proximity rules (such as driving on sidewalks). In 2013, the Panasonic Corporation conducted research related to the use of radar waves in vehicles to detect

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[37] Cottrell and Barton, "The Role of Automation in Reducing Stress and Negative Affect while Driving," 53–68.

[38] Wit, "Vector Pursuit Path Tracking for Autonomous Ground Vehicles,"

[39] Shmizu and Poggio, "Direction Estimation of Pedestrian from Images,"

obstructions, such as pedestrians and other vehicles; this literature provides examples of how current technology can be implemented into emergency vehicles to improve safety during response and to bystanders.[40] The use of AS can decrease the incidents of emergency vehicle collisions through integration of the technologies discussed as expressed by Custalow and Gravitz in "Emergency Medical Vehicle Collisions and Potential for Preventative Intervention."[41] Emergency vehicles travel to emergency scenes a high rates of speed, bypass routine "rules of the road," and often travel in groups (more than one emergency vehicle responding to a single location).

C. CAR-TO-CAR TECHNOLOGY

C2C communication, known as "connected vehicles," is the ability for autonomous cars to communicate with each other and an engineered environment that serves as the communication hub to permit AS functionality. The Joint Program Office, a U.S. Department of Transportation Agency, publishes a wide range of literature that focuses on Intelligent Transportation Systems including connected vehicles.[42] Information published by the Joint Programs Office provides a broad and high-level literature source that will be used to assist in explaining the core components of connected vehicle technologies. DSRC is a component that electronically sends messages from a source, such as a roadway warning system, to a vehicle so that the on-board driver information system will be alerted to hazards ahead.[43] This type of communication can alert drivers, or even possibly cause vehicles to pull to the side to permit emergency vehicles to pass safety, or keep accident scenes safe from vehicles operated by unaware drivers.

Figure 4 illustrates how cars will be connected not only to each other, but also to the built environment through the use of DSRC. By leveraging data from a car, other

[40] Panasonic Corporation, *Panasonic Advances Automotive Millimeter-Wave Radar Technology to Detect Pedestrians and Vehicles in Low Visibility Conditions*.

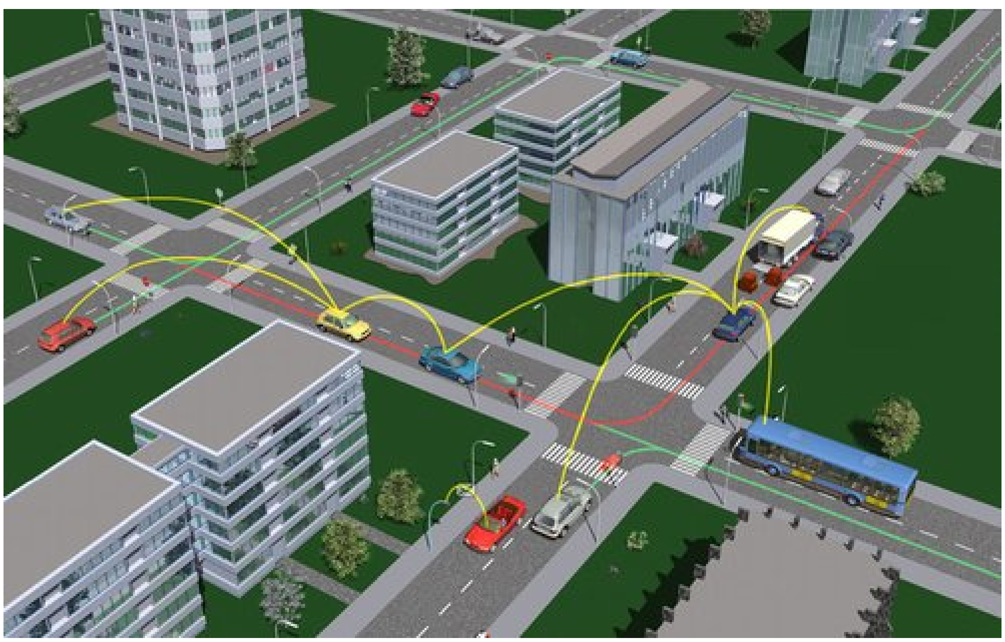
[41] Custalow and Gravitz, "Emergency Medical Vehicle Collisions and Potential for Preventive Intervention," 175–184.

[42] Intelligent Transportation Systems, Joint Program Office, *Connected Vehicle Research*.

[43] Clemson University Vehicular Electronics Laboratory, "Dedicated Short Range Communications,"

vehicles will be able to avoid collisions, automatically select a lane that will provide the most expedient route of travel, be notified of road hazards and detours, and trigger the activation of other interconnected systems.[44] C2C technology will enable drivers to program their selected fuel vendor, restaurants, mechanics, and other services into the onboard data systems so that the operator (or in the future, the fully automated vehicle) will be advised when to get fuel at the preferred location or simply have the vehicle auto-route to the fuel station at a prescribed fuel level or distance. Additionally, coordination with the built environment enables drivers to be aware of construction zones, and instantly receive detour information, alternate route options, and emergency and hazard messaging.

Figure 4. Car-to-Car Technologies



Source: "Mission and Objectives," accessed June 8, 2015, https://www.car-2-car.org/index.php?id=5.

[44] MIT Technology Review, "Car to Car Communication: A Simple Wireless Technology Promises to Make Driving Much Safer," 2014, http://www.technologyreview.com/featuredstory/534981/car-to-car-communication/.

D. RELEVANCE TO EMERGENCY MEDICAL SERVICES

Figure 5 identifies 14 attributes of EMS systems, and all of these attributes will be impacted by the development and implementation of AS.

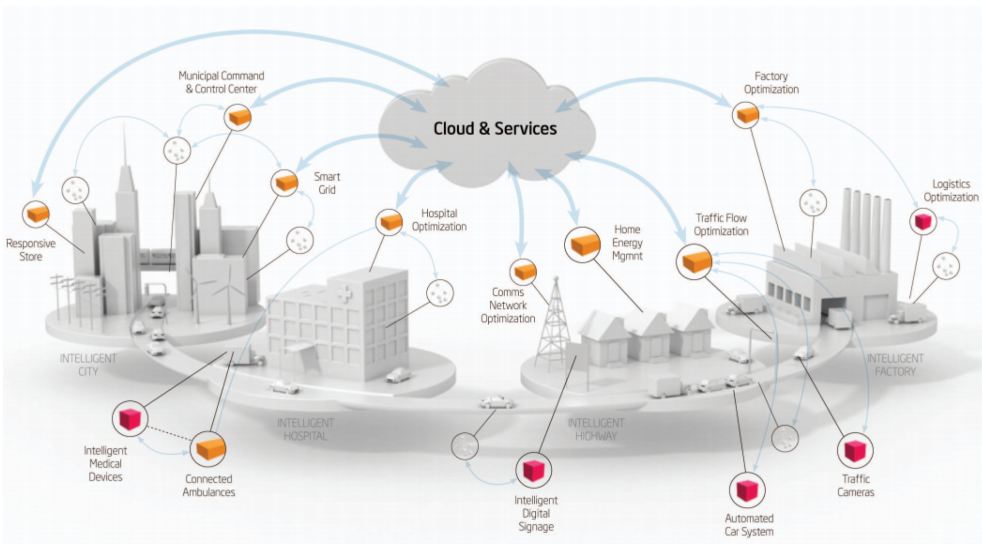
Figure 5. Emergency Medical Services Agenda for the Future

1.	Integration of Health Services
2.	EMS Research
3.	Legislation and Regulation
4.	System Finance
5.	Human Resources
6.	Medical Direction
7.	Education Systems
8.	Public Education
9.	Prevention
10.	Public Access
11.	Communication Systems
12.	Clinical Care
13.	Information Systems
14.	Evaluation

Source: "Emergency Medical Services Agenda for the Future," 1996, http://www.nhtsa.gov/people/injury/ems/agenda/emsman.html.

The evolution of AS will have a great impact on EMS systems, and in fact, will change the way emergency services organizations operate in the not so distant future. The networking of data through cloud-based technology, sharing of millions of data elements, coordination of moving vehicles, and two-way data exchanges will not only provide benefits to EMS systems but may cause unanticipated consequences for the EMS provider that is not ready to integrate with or has considered AS. The next two chapters will focus specifically on issues related to integration and consideration of AS within EMS systems. However, Figure 6 provides an easy to understand illustration of how AVs, using the IoT and C2C technology, will communicate to tie together services, systems, and equipment.

Figure 6. Car-to-Car and the Internet of Things Integration



Source: "The Internet of Things," accessed June 23, 2015, http://www.opinno.com/en/content/Internet-things-0.

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IV. THE USE OF AS IN EMERGENCY MEDICAL SERVICES TODAY

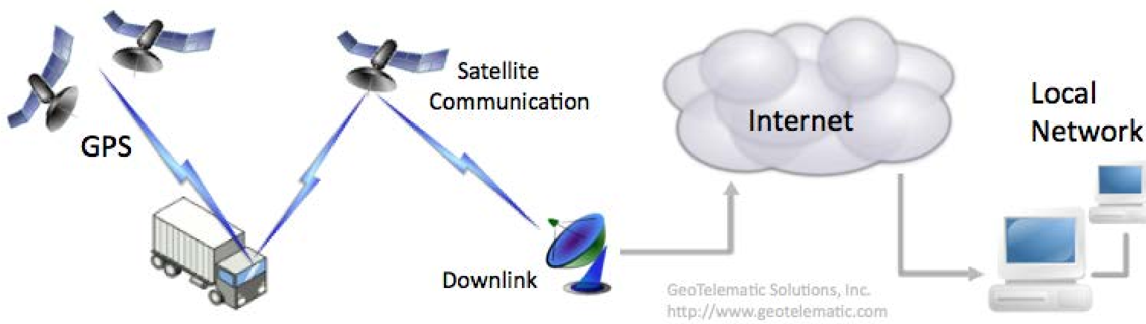
The future of EMS provision will continue to be highly influenced by the use of ever-expanding technology related to AS including vehicles, as well as devices that are part of the IoT specific C2C technologies. Fully automated systems, such as self-driving ambulances, are not yet available for non-experimental use; however, the systems that support AVs and related systems are on the market today. A wide range of support systems are able to communicate through the IoT to make the provision of EMS more efficient and potentially provide better patient care.

Contemporary EMS systems are using the IoT today to help support routine operations. These include resource allocation tools, audio and video integration, remote operations control, and telemetry systems. Most EMS providers use each application independently rather than as an interconnected system. An interconnected system has advantages as multiple sources of data can be collected, aggregated, and then analyzed to amplify the value of any one of the inputs or outputs. An example is the collection of data that results in activating an automated response by another system, which in turn, triggers other system activities. Detailed examples are provided in each of the following sections, as the interconnection of systems is a key to implementing and understanding AS successfully.

A. MAPPING AND ROUTING SYSTEMS

Speed and accuracy of resource selection are key components of EMS operations. EMS personnel must be able to locate incident scenes quickly, determine the most appropriate and fastest route, select the most appropriate unit to respond, and then be able to navigate to the closest and most appropriate hospital when transporting a patient in need of definitive medical care. GPS systems have generally replaced the use of traditional maps in most emergency medical response organizations. GPS systems use location data provided by an in-vehicle sensor that communicates with one or more satellites (See Figure 7). This data is then displayed on an electronic map that shows the location of the vehicle, a route of travel, and other data, such as speed, estimated time of arrival, and alternate routes. The majority of GPS systems is inexpensive, offer additional services, such as voice prompts, traffic congestion information, and may display other available services, such as food, fueling stations, and other landmarks of interest to the operator.

Figure 7. Global Posting System Architecture



Source: GeoTekematic Solutions, Inc., accessed July 31, 2105, http://geotelematic.com.

The GPS system described is an interconnected system itself, as it collects data from the satellite and then displays it on an electronic map loaded into a piece of hardware located inside the vehicle. Automatic vehicle location (AVL) systems include GPS and use sources other than satellites including radio frequencies and microwave data determine the location of a vehicle. Using AVL and GPS as a core integrated foundation, EMS providers may expand into the use of AS to further leverage data to enhance operations.

B. STANDARDS OF COVER AND RESOURCE ALLOCATION

Standards of coverage, system status management, or deployment planning all refer to an EMS organization’s method for ensuring that responders are able to make it to the scene of an emergency in a predetermined period of time. In the past, the process of determining resource deployment took a great deal of time and analysis, as response logs had to be reviewed, complied, and then compared to deployment journals and dispatch records. Deployment plans were then revised and implemented, but it would take time to assess the impacts of a deployment change, which could mean that response times failed to improve, remained the same, or perhaps even become slower.

The addition of GPS/AVL enabled the deployment planning process to improve but caused emergency response units to be constantly moved from location to location to provide coverage to predetermined areas.[45] These static posting locations assumed a certain amount of responses would occur in a given area and resources were placed on standby in these areas. The movement of units is costly not only in the sense of fuel costs, but in the loss of unit availability if a response occurs as vehicles are moving from area to area and are actually missing responses as they move to cover static standby locations. The use of GPS/AVL technology has enabled deployment planning to shift from set physical ambulance stations as a center point for deployment to softer field-based locations that constantly shift to meet the daily trending of emergency calls that occur within a given jurisdiction. The shift to field-based deployment over stations has resulted in faster response times, but also tends to create secondary concerns, such as increased fuel use from ambulances being constantly on the move, crew fatigue from not having a set location to rest and prepare meals, and public perception concerns related to engine idling, which causes increased production of carbon gas also known as "greenhouse gasses."[46]

The interconnection of various AS now enables coverage to be projected near real time using vehicle dispatch probabilities for estimating coverage.[47] Unlike using GPS/AVL alone, interconnected systems tie together historical call volume, traffic patterns, computer aided dispatch (CAD), historical ambulance movement data, standby and deployment plans, and vehicle analytics, which provide a broader and more comprehensive view of the entire EMS system or coverage area. Computer aided

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[45] Luiz Augusto C. G., Andrade and Claudio B. Cunha, "An ABC Heuristic for Optimizing Moveable Ambulance Station Location and Vehicle Repositioning for the City of Sao Paulo," *International Transactions in Operational Research* 22, no. 3 (2015): 473–501.

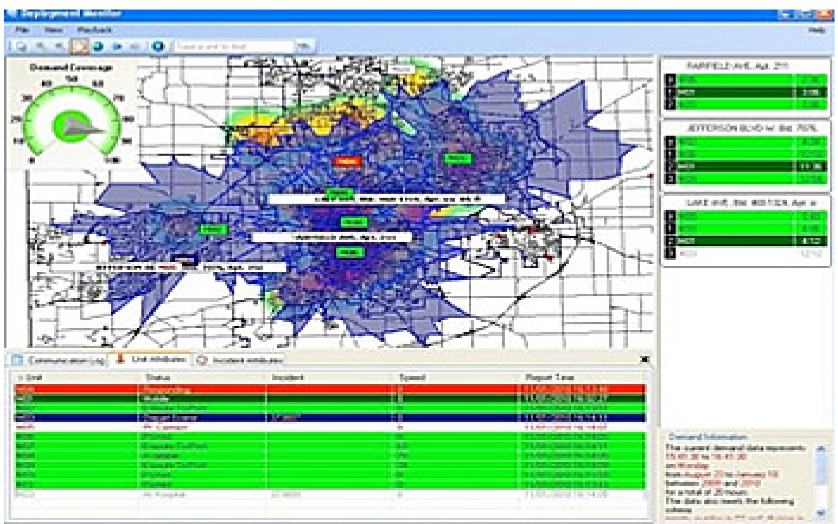
[46] Ibid.

[47] Susan Budge, Armann Ingolfsson, and Erhan Erkut, "Approximating Vehicle Dispatch Probabilities for Emergency Service Systems with Location-Specific Service Times and Multiple Units per Location," *Oper. Res.* 57, no. 1 (2009): 251–255.

dispatch systems are then able to integrate hardware and software solutions to maximize the benefit of the analyzed data using these diverse inputs.[48] The leveraging of multiple data sources results in ambulances not only being placed in areas most likely to receive a request for emergency service, but provides information for human operators that can assist with controlling fleet costs, assuring personnel welfare and health, and minimizing waste.

Figure 8 is a screen capture from the prediction software product MARVLIS produced by Bradshaw Consulting Systems. The program uses multiple data sources to graphically illustrate system demand and provide recommendations for resource allocation real-time.

Figure 8. Prediction Software



Source: StatEMS, accessed July 31, 2015, http://www.statems.net

Cycle time and fleet size are important factors in determining how coverage will be provided to a given response area. "Cycle time" or "time on task" refer to the amount of time a unit, in this case an ambulance, is not available to perform emergency response activities. It includes the time when an ambulance is already assigned to a response, as

[48] Business Editors, "Illinois State Highway Toll Authority Selects Geac Public Safety's EnRoute Computer-Aided Dispatch System," *Business Wire*, April 12, 2001, 1, http://search.proquest.com/doc view/445849358?accountid=12702.

well as periods of maintenance, crew change, rest/meal breaks, moving from one standby location to another, hospital waiting times, and any other activity that makes a resource not available for response. To compensate for lost hours, additional units must be placed in service to balance actual response hours with the administrative activities necessary to provide services. Balancing fleet size along with realizing operational efficiencies through high "time on task" activities are key elements of queuing theory.[49] By using various systems described earlier, EMS services may be able to streamline operations that reduce or eliminate unnecessary down time, increase time on task, and reduce costs thorough more efficient use of limited resources by scheduling tasks based on geographical need, during low-call volume periods, and sequence non-emergency activity in ways that keep deployment high by leveraging multiple and simultaneous task completion.

C. AUDIO AND VIDEO INTEGRATION

Audio and video systems have been standard components in most passenger and commercial vehicles for decades. The primary purpose of these systems is to provide entertainment, which may include access to wireless Internet connections as drivers and their passengers travel to their intended destinations. The use of audio and video for EMS providers have remained fairly limited even with the extensive progression of access in the commercial and passenger vehicle markets. Concerns over privacy, both personally identifiable information (PII) and healthcare information, requires that EMS providers develop, implement, and strictly monitor the how data is collected, used, and stored.

Dash mounted cameras, including audio recording, have been fairly common place in police cars for well over a decade and have made their way onto ambulances in the past few years. These cameras have offered an outstanding source of data to help in the post-incident review of multiple patient incidents, disasters, EMS responses, and after action reports. Video that is captured during events can be integrated with other data typically used for reviews including radio communications, written reports, responder

[49] Marcos Singer and Patricio Donoso, "Assessing an Ambulance Service with Queuing Theory," *Computers & Operations Research* 35, no. 8 (2008): 2549–2560.

accounts, GPS data, and news footage. The primary focus of quality improvement review is determine the root causes of failures or variances from standards and then implement corrective actions. Video review enables quality improvement personnel to replay the event, focusing on not only the general operational characteristics but also the technical and tactical aspects. Many of these more subtle variances would be likely missed through a routine review, as these key details may be not recognized through a standard review process.

While the use of collected audio and video is a great resource for quality improvement, its primary benefit is for safety. Cameras that are typically used in ambulances are directed to capture the roadway to the front of the vehicle, the rear, and within the driver's compartment. The placement of cameras in this fashion enable the collection of simultaneous data from independent perspectives to help paint a comprehensive set of video that illustrates an occurrence. EMS services have used this video in documenting collisions where drivers have failed to yield to ambulances operating with lights and sirens, patients who have fled the ambulance, patients who have assaulted EMS providers, and to capture on-scene behavior that may be illegal. The cameras are also useful to EMS provider agency risk managers as personnel may be captured driving irresponsibility, violating policies and procedures, or participant in activities that are in opposition to the organizations mission, vision, or values.

Vehicles equipped with cameras download collected data through wireless transfer points. Most EMS services place these transfer points at deployment centers or field-based locations that may include hospitals, fueling stations, and supply depots. In the future, near-range communication systems will enable the data to be download in smaller portions and over longer periods of time, as the roadway system will be "connected" at all times to enable almost real-time video transfer. Real time video transfer is available today; however, the bandwidth required is great and the quality of streaming images is far less than high-definition.

The costs of acquiring video data is relatively inexpensive; however, the true cost is in the storage and download of the data. The administrative processes required to maintain privacy and security of the data are also very expensive. Terabytes of information are collected and must be retained for significant periods of time, all resulting in increased costs. It is likely that as C2C technologies develop, the role of audio and video devices will grow a great deal, and therefore, the cost of services should decrease as market demand increases.

D. REMOTE OPERATION CONTROL

Remote operation control is the ability to control a technological device through wireless connections that could include the Internet, radio frequency (RF), infrared (IR), or other communications pathway. Collaborative control is a term that describes the interconnection between artificial intelligence and the human in regard to decision making and subordination.[50] This type of collaboration is designed to permit not only the human to evaluate the activity of the "machine," but permits the "machine" or artificial intelligence to determine the amount of human input that may be applied to a given scenario. This concept of remote control is designed to make the intended operation the safest and most appropriate for the given scenario but requires extensive programming and "learning time" for the artificial system to apply human logic and past performance to a current situation. In the future, Collaborative control systems will be embedded in the lives of humans every day activity much like the almost transparent IoT is today.

Remote operation is in practice today in a variety of applications related to EMS. One of the most common devices is the use of traffic signal emitter technologies that receive a signal from an approaching emergency vehicle that triggers the traffic control unit to respond. The traffic control unit receives an input that indicates the direction of travel for the emergency vehicle and turns all other traffic signals red and to green in the emergency vehicles' intended travel path. The problem with the current generation of these systems is that multiple emitters and traffic control units exist that no not share common activation protocols. Therefore, even if a traffic signal is equipped with a device, it may not be able to understand the electronic signaling required to change the

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[50] Terrence Fong, Charles Thorpe, and Charles Baur, "Advanced Interfaces for Vehicle Teleoperation: Collaborative Control, Sensor Fusion Displays, and Remote Driving Tools," *Autonomous Robots* 11, no. 1 (2001): 77–85.

light. The range between the approaching emergency vehicle and the traffic control device is limited today; it is basically line of sight.

Traffic control devices have proven to be a beneficial device in saving lives and decreasing response time to the scene of an emergency.[51] The primary method by which the system provides increased safety is by stopping unwanted and competing traffic flow, such as cross traffic and other transportation system, such as busses and trains. With cross traffic stopped, vehicles traveling in the same direction as the emergency vehicle will be able to safely pull to the side to permit them to pass and will not become a barrier at red lights by blocking intersections. The lack of traffic enables emergency vehicles to travel with less obstructions, which reduces response time.

Emergency vehicles transmit a signal to a traffic light based receiver that signals the light to change to green in the direction of travel and to red in all other directions (Figure 9).

Figure 9. Traffic Signal Control Graphic

Source: "SunGuide Disseminator," accessed August 5, 2015, http://floridaits.com/01ITSGC/doc-NL/2008/02/Feb08.htm.

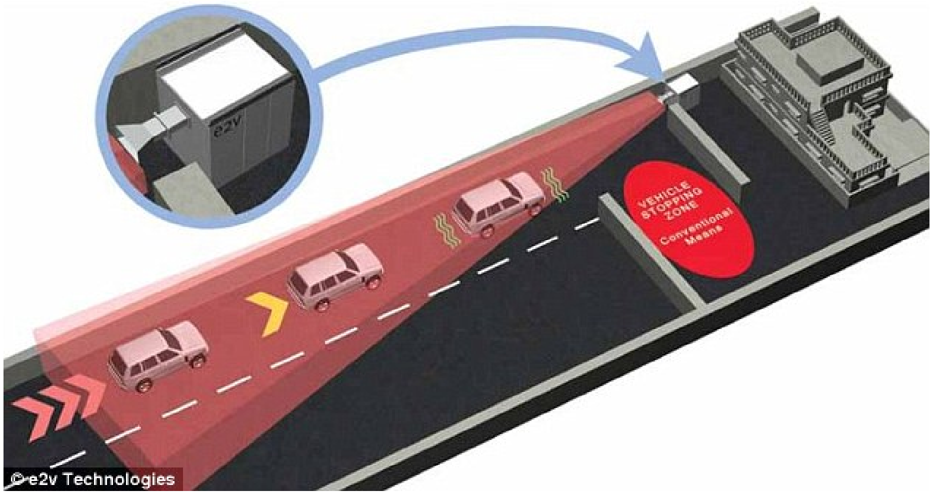
[51] Pitu B. Mirchandani and David E. Lucas, "Integrated Transit Priority and Rail/Emergency Preemption in Real-time Traffic Adaptive Signal Control," *Journal of Intelligent Transportation Systems* 8, no. 2 (2004): 101–115.

The majority of emergency vehicles that are in service today operate using a complex network of technology that enables the vehicle to operate with efficiency while providing information helpful to human operator. Sensors, transmitters, and relays are components that make a modern vehicle work. They are responsible for climate and comfort control systems, engine operation, vehicle tracking (GPS), maintenance notifications, and safety systems. These systems are interconnected and most have an interface that enables wireless transmission of data from the vehicle to a variety of receivers ranging from vehicle manufactures, entertainment systems (XM and Sirius), and third-party applications. One such application type enables an EMS provider organization to control deployed vehicles remotely and is known as remote vehicle disruption (RVD) systems.

A RDV system collects data transmitted from an equipped vehicle and then remotely accesses controls to enable a user to override a human operator. The simplest example of this technology is the ability for a car manufacturer to unlock owners' vehicle remotely when they have locked the keys or access device within the vehicle. In regard to EMS, the ability to take control of an ambulance or stop unauthorized vehicles is critical.

Ambulances may need to be stopped for a variety of reasons including theft and hijack/hostage scenarios. In cases during which an ambulance is in operation, the vehicle can be remotely controlled by accessing engine and safety controls that will first slow the vehicle, secure the doors and windows, and then stop the vehicle when law enforcement are prepared to take action. Mapping systems permit the remote operator to track the vehicle while coordinating a law enforcement response similar to the way antitheft systems, such as a LoJack vehicle recovery system operate. Unoccupied vehicles can be simply disabled at any time to render them useless to the thief or terrorist. Other remote devices emit signals from transmitters that can disable unauthorized vehicles from accessing secure facilities (Figure 10). These systems are not routinely used today due to the lack of short-range communications systems and C2C technology but offer great opportunities in the near future.

Figure 10. Remote Vehicle Disruption



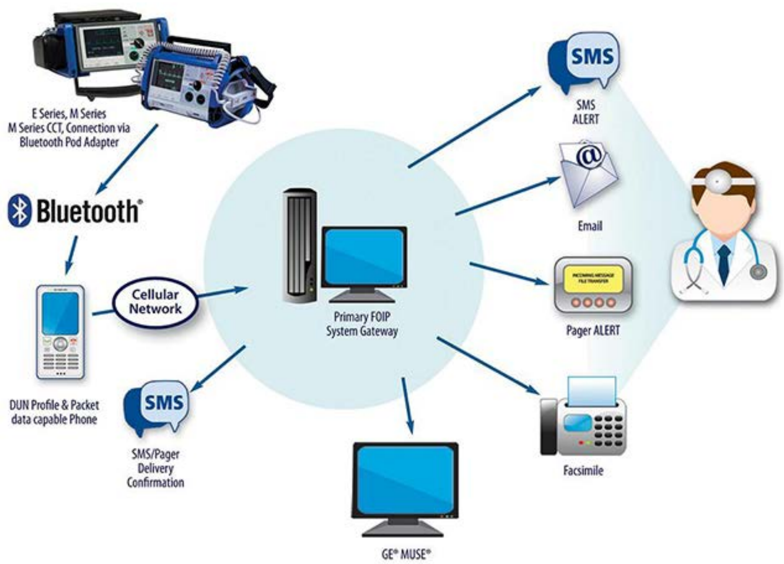
Source: "End of the High-speed Car Chase? Engineers Invent System that Disables a Vehicle's Engine Remotely Using Radio Beams," accessed July 31, 2015, http://www.dailymail.co.uk/sciencetech/article-2518177/RF-Safe-Stop-disables-vehicles-engine-remotely-using-radio-beams.html.

E. TELEMETRY INTEGRATION

EMS provides medical care in the field setting to stabilize patients and then provide transport to those in need of definitive care in an acute care hospital. The EMS in-field environment consists of a wide range of technical devices including radio systems, cardiac monitors, 12-lead electrocardiograms, electronic medical records, and vital sign monitors, which are known as telemetry devices. The majority of these peripherals have the capability of connecting to a wireless network installed in the ambulance so that data can be transmitted to the EMS provider's network or to other receivers, such as hospitals.

Cardiac care is a key component of EMS response. The phrase "time is muscle" refers to the death of cardiac tissue caused by a blockage in the blood supply to the heart. Rapid recognition of this type of blockage is essential, as is speedy transport to designated cardiac care centers. A cardiac care center can use chemical or surgical mechanisms to attempt to destroy lethal clots, which cause roadblocks in the blood supply. Specialized surgeons and cardiologists must be made aware of a potential case as soon as possible so as not to delay the administration of potentially life-saving procedures. Paramedics are now able to send a 12-lead electrocardiogram from the field to the emergency department or a variety of electronic devices, such as pagers, smartphones, fax machines, and emails (Figure 11); thereby, remotely activating the cardiac catherization team while the patient is still in the field setting.[52]

Figure 11. Medical Telemetry Architecture Example



Source: Ostitech, accessed July 31, 2015, https://www.ositech.com/applications/pre-hospital-ecg-transmission.com.

Vehicle-based telemetry collects data from various sensors located within the vehicle itself including speed, acceleration/deceleration, status of emergency signaling devices, as well as red lights and siren, and virtually any element that provides sensory data. The purpose of vehicle data collection is to improve driver performance so that the operator receives feedback that can improve safety and reduce costs related to vehicle operation and accidents.[53] "Event capture" is an automated process that assesses a

[52] Kjell C. Nikus et al., "How to Use ECG for Decision Support in the Catheterization Laboratory: Cases with ST-Segment Depression Acute Coronary Syndrome," *Journal of Electrocardiology* 37, no. 4 (2004): 247–55.

[53] Jane H. Brice et al., "Special Section: Safety in EMS," *Presented at the National Association of EMS Physicians Ambulance*, Phoenix, Arizona, January 2010.

driver's performance through the collection of data generated by sensors as the vehicle is operated and when a predetermined condition occurs. For example, an EMS provider agency may establish acceptable speed, breaking and acceleration, as well as camera activation while the ambulance is operating with emergency lights and sirens. When the criteria is met, a predetermined trigger will capture all available data for that event and then may issue alerts in the form of reports, emails, or other data streams. The combination of vehicle data information with driver accounts provides the opportunity to improve safety by improving the evaluation of qualifying episodes (such as a collision).[54]

F. CHAPTER SUMMARY

This chapter has described the technology currently in place in EMS related to AS including vehicles, devices that are part of the IoT, and specific C2C technologies. Technology has greatly assisted EMS provider organizations; however, the full value of these systems is yet to be recognized. The next generation of AS will leverage existing technologies and further interconnect systems into even more complex networks of data sharing, automation, and artificial intelligence. Today's technologies are generally piecemeal, independent systems that may integrate with other systems but in an unrefined fashion leading to glitches, the need for complex interfaces, and less than ideal solutions. The architecture of the future provides solutions to the majority of today's technological ailments; although new dilemmas and security concerns will also develop, EMS providers will have a new set of tools at their disposal to improve safety, efficiency, and effectiveness.

The next chapter will illustrate how the current technologies detailed in this chapter will be integrated into more robust and highly efficient technology system in the future. Understanding what comes next is difficult to project in great detail, as the speed at which AS develop and undergo metamorphosis is truly astonishing. What is known is that all new vehicles will have artificial intelligence that dwarfs the most advanced systems on the market today, that human intelligence will be challenged by machines,

[54] Jane H. Brice et al., "EMS Provider and Patient Safety during Response and Transport: Proceedings of an Ambulance Safety Conference," *Prehospital Emergency Care* 16, no. 1 (2011): 3–19.

and that our lives will become even more interconnect than we currently realize. The growth and speed of technological development means that ideas that previously took one or two generations to create and implement may be reduced to years, or even weeks, in some cases.

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V. THE AUTONOMOUS SYSTEMS OF TOMORROW IN EMERGENCY MEDICAL SERVICES

In the previous chapter, AS including the IoT, C2C technologies, and driverless cars were presented in relation to how they are used in contemporary EMS systems. The degree of technology used in American EMS systems is increasing but it has yet to be integrated in the fashion and depth that is contemplated to occur in just the next decade. This chapter will focus on what should be expected in the 10 to 20 years in relation to how the IoT, DSRC, and autonomous EMS vehicles including the use of C2C technologies will become an operational aspect within EMS systems.

The speed of technological advancement is ever increasing as processes become more streamlined, development costs decrease, and the consumer market demand increases. The evolution of the cellular telephone is a good example of a technology that underwent continuous upgrades and enhancements that led to a change in the entire purpose of the technology. The need for wireless telephone communication was the basis for the development of the mobile phone so that users could communicate anywhere, not just in places where a hard wire telephone was available. Mobile telephones became smaller, more powerful, and more reliable, while the market for them exploded. Consumers had a wide range of choices in mobile phone hardware, styles, and features, yet all of the devices basically provided the same set of capabilities. The mobile phone then began its transformation by integrating other capabilities and technologies, such as calendars, address books, calculators, and messaging, leading to next generation technologies that drove consumer preferences and choices. Today's mobile telephone is rarely used as voice communication device, its cornerstone capability. "Smartphones" and "digital assistants" now offer mobile services in a variety of formats that have transformed the utility of the device from a voice communication tool to a mobile computer. It is likely that the same will hold true for AS growth. The unknowns are great and users will be challenged to keep up with the speed and ever growing utility of the technology.

A. RETURN ON INVESTMENT: THE NEED FOR AUTONOMOUS SYSTEMS

EMS systems in the United States generally operate on very lean budgets, and rely heavily on the payment of services by insurance companies or the patients when they are transported to a hospital. Current insurance programs, including those funded by the federal government, do not cover costs associated with non-transport situations. Local taxes or fees may help to subsidize the cost of providing EMS in government-based EMS organizations yet most EMS providers in the United States are volunteer non-profit organizations or private services.

The ACA has had a significant impact on EMS that may be described as a two-edged sword.[55] The ACA has provided a large number of people with either free or affordable health care insurance that they may not have had access to in the past. The additional lives that are now insured have caused increases in EMS system call volume, as well as hospital emergency departments across the nation. In areas where large numbers of patients were high users of EMS, and did not have health insurance, which resulted in the lack of revenue or indigent care, the ACA has proven to be beneficial to help offset some of the costs associated with what was previously considered uncompensated care. The impact to other communities has not been as positive, as the number of people holding private insurance plans have decreased and been replaced with higher deductible plans. Many of the previously uninsured are now insured though federal plans, such as Medicare or Medicaid.[56]

The majority of EMS providers use a system known as “balanced billing.”[57] Balanced billing means that the users of the EMS system that pay higher rates, such as those covered under private insurance plans, support the lack of payment from other users or the indigent. Private insurance services generally pay about 80% of the billed charges,

[55] U.S. Department of Health and Human Services, “Key Features of the Affordable Care Act,” accessed August 30, 2015, http://www.hhs.gov/healthcare/facts/timeline/index.html

[56] America’s Health Insurance Plans. Center for Policy and Research, “Affordable Care Act,” accessed August 4, 2015, http://www.ahip.org/Issues/Affordable-Care-Act/.

[57] U.S. Centers for Medicare and Medicaid Services, “Balance Billing,” Healthcare.Gov, accessed August 30, 2015, https://www.healthcare.gov/glossary/balance-billing.

as long as the charges appear “reasonable and customary” for the services provided, as well as the market. However, federal insurances pay much less. For example, an average ambulance transportation bill in California may be somewhere around $2,300.00 including mileage, a base rate, and services provided by the ambulance personnel. A private insurance service would likely pay about 80% of the bill and then collect from the patient, who is responsible for paying the balance. Medicare will likely pay approximately $450.00 and Medicaid would likely pay about $150.00 regardless of the actual costs associated with a service provided. Federal insurances prohibit the EMS provider from collecting additional revenue from the patient once a federal claim has been made. In other words, EMS service providers almost always collect pennies on the dollar to cover their cost of service.

The ACA also contains provisions that focus on quality and efficiency. Medical necessity has long been a core component of all health care insurance services as a means to assess appropriate use of EMS services by patients. The intent of medical necessity evaluations is to provide only the minimum level of service required for the patient’s condition. Most Medicare and Medical fraud is related to unnecessary use of ambulances to move a person from one location to another when a cheaper form of transportation could have been used, such as senior van service, taxi, or other non-medical service option. The ACA takes this type of utilization to a higher level and foceses on indicators, such as if the patient was admitted to the hospital, the hospital admission and discharge diagnosis, and if the patient returned to the hospital within 30 days of release.[58] After review, the amount of payment made to an EMS provider or fines incurred by the hospital can result in significant reductions in payment from federal insurances.[59]

Decreasing healthcare funding requires that EMS providers find more efficient and effective ways of providing critical and sometimes life-saving services cheaper. In most EMS organizations, personnel costs represent the biggest budget line item along with vehicle purchase and maintenance costs, fuel, and medical supplies. Understanding

[58] Nancy-Ann Deparle, “The Facts about the Independent Payment Advisory Board,” The White House, accessed August 5, 2015, https://www.whitehouse.gov/blog/2011/04/20/facts-about-independent-payment-advisory-board.

[59] Ibid.

that the profit margin for most private ambulance services is very small and will continue to decrease because more people are using EMS services but are paying less, EMS systems will benefit from leveraging AS. The use of AS including the IoT, C2C technology, and AVs may have significant start-up costs but will enable services to be provided in different ways, more effectively, and integrated with the larger connected world.

EMS services that do not embrace emerging technologies will likely be left behind, and with some exceptions, will fail to exist. The challenge for EMS services is to decide when to enter the game; an early entry may result in high costs and use of unproven technologies; a late entry may mean that other market forces have taken over and bypassed the need for the service. EMS services will change based on the continued emergence of AS, and early evaluation of work processes and modification of operations are critical to the determination of the return on investment. In some EMS services, the increased use of the IoT may be the least costly method of realizing efficiencies providing human users with more data to make better decisions. In other organizations, complete replacement of systems and methods of operation may transform a business into a highly competitive entity commanding market domination.

B. DEDICATED SHORT-RANGE COMMUNICATION/INTERNET OF THINGS

EMS services have been a user of various tools that leverage the use of the Internet for many years. In the last chapter, systems including resource allocation tools, audio and video integration, remote operations control, and telemetry, were discussed in relation to how they are being currently used by EMS providers. This section will introduce how current systems may be transformed and which new capabilities offer promising enhancements to today's solutions.

DSRC is a wireless system that permits vehicles to communicate with one another, or vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), to integrate various resources with a focus on intelligent transportation systems.[60] In 1998, the

[60] Clemson University Vehicular Electronics Laboratory, "Dedicated Short Range Communications."

Transportation for Equity Act for the 21st century directed the Federal Communications Commission to allocate a spectrum "for the operation of intelligent transportation systems, including spectrum for the dedicated short-range vehicle-to-wayside wireless standard."[61] DSRC will provide a new level of integration that will connect infinite numbers of sensors with analytics to offer users intelligent recommendations on road selection, safety, convenience, emergency assistance, and a virtually limitless menu of interconnected opportunities.

Aside from connecting to a limitless network through V2I communication, DSRC provides many advantages that will be realized as soon as C2C technologies begin to hit the market in 2016. The primary benefit of C2C technology is that external infrastructure is not required for cars to communicate to and through each other. Therefore, even in the most remote of areas, cars will be able to act as mobile repeater systems, essentially bouncing messages from C2C as they come into range if they are produced after 2016 when the minimum DSRC components are mandated requirements in newly made U.S. vehicle models. This level of new connectedness will almost instantly improve safety by issuing collision alerts, advising drivers of hazardous road conditions, and establishing emergency communication networks should a driver become distressed by mechanical breakdown or personal emergency.

DSRC combines V2V communications with V2I communications capabilities using electronic gateways, sensor sites, or other short-range data collection infrastructure. These communication linkages enable individual vehicles to be linked with virtually any system that has the ability to connect with the network through servers and their applications (Figure 12).

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[61] Luca Delgrossi and Tao Zhang, "Dedicated Short–Range Communications," *Vehicle Safety Communications: Protocols, Security, and Privacy*, 2009, 44–51.

Figure 12. Dedicated Short-Range Communication Systems

Source: "Short Wave or Short Range," accessed August 23, 2015, http://swling.com/blog/2013/01/short-wave-or-short-range.

DSRC will change the way EMS operates when responding to calls for service by leveraging new communication pathways enabled by the newly expanding technology. The last chapter provided some examples of systems that use the IoT to aid emergency responders in doing their job more efficiently and effectively. This section will identify the operational components of an EMS response and how DSRC will provide benefits to the responders, as well as the people served by emergency responders.

EMS use of DSRC and other related IoT technologies may be divided into the following six components of service provision: (1) situational awareness/call prediction, (2) receipt of an EMS call, (3) response, (4) on scene operations, and (5) patient transportation.

1. Situational Awareness/Call Prediction

Situational awareness is a core component of EMS operations, as systems must be prepared to serve populations as demand increases and changes throughout the day. In today's modeling, call volume prediction is generated from archived data collected from past responses from a variety of sources including GPS/AVL, computer aided dispatch, patient care records, and historical patient transport volume.

DSRC will bring a new level of data transmission that will help responders to predict call volume better in near real time and real time. Proper deployment includes understanding where people are located, their movement, and identification of how many people are in motion at any one time. The movement of large numbers or even groupings of people usually result in the generation of an EMS response. Sensors in vehicles and connected infrastructure will trigger alerts when large numbers of people begin to move within the jurisdiction, which may include routine volume surges when large businesses, schools, or entertainment venues begin or end events. These triggers will enable emergency responders to adjust staffing and position response resources accordingly to meet demand while controlling the costs of unnecessary deployments.

Point of sale (POS) data collected in pharmacies and supermarkets can be aggregated and then geographically tagged to provide early warning of the emergence of flu-like symptoms through the sale of over the counter remedie, as well as prescription medications. The identification of the type of medication and the geographic distribution of patients using various medications can assist responders in early recognition of suspected biological attacks, which are most commonly treated by antibiotics. The data collected from POS alone is not a robust indicator that would enable responders to take action in most cases, but if POS information were combined with data collected from DSRC that shows traffic volume is lower than usual, drivers routinely reporting to various locations have decreased, it would provide an early warning of a potential critical situation.

The collection of data available through the hundreds of sensors in connected vehicles will provide intelligence to emergency planners in regard to public threats, such as heat and cold advisories, road closures, air quality (smoke and chemical presence), assessment of precipitation, as well as the location of the vehicle. The amount of routine data collected and analyzed will establish a routine baseline to which daily variances can be compared. These variances may be indicative of conditions that could result in increased illness or injury within a population or geographic region.

While DSRC will assist responders in the identification of potential or actual emergencies, collision avoidance through connected vehicles will improve the safety of drivers in the very near future by preventing many motor vehicle related injuries and deaths including collisions with emergency vehicles.[62] Connected vehicles constantly communicate with each other, and provide advisories to the operator, as well as take automatic action to avoid collisions. The benefits of connected vehicle technology are exponential but will be greatly dictated by the consumer or future safety related laws. An example is that a vehicle would fail to disengage from park until the operator and all passengers were wearing seatbelts, wireless communications devices were placed in secure “hot spots” that kept the drivers hands free to operate the vehicle, and perhaps a blood alcohol ambient air test could be completed before engaging the transmission. Regardless of the degree of sensor integration, cars actively avoiding other cars and people will decrease EMS call volume related to vehicle collisions.

Sensory technology that links vehicles and systems for a wide variety of purposes can be leveraged within EMS in areas, such as missing persons, medically at-risk patients, and selected fugitives.[63] Placing sensors on at-risk persons will enable connected vehicles, including emergency response units to issue a notification if a person is within range of a connected vehicle. This technology will help locate or identify persons not able to care for themselves or those who may represent a risk to the general public, such as a tuberculous patient not compliant with a treatment regimen, a violent psychiatric patient, or simply, a senior experiencing late stage dementia.

2. Receipt of an Emergency Medical Service Call

EMS calls are generally received by public safety answering points (government dispatch centers) by mobile or landline phones. In addition, some enhanced 911 public safety answering points now accept text and video based calls as well. DSRC facilitates automated alerting from connected vehicles that is not currently an available technology

[62] Custalow and Gravitz, “Emergency Medical Vehicle Collisions and Potential for Preventive Intervention,” 175–184.

[63] Heather Kelly, “Sensors Let Alzheimer’s Patient’s Stay at Home, Safely,” *CNN*, August 25, 2014, http://www.cnn.com/2014/08/25/tech/innovation/alzheimers-smart-home/

that will activate based on programming variances or by request of a human operator or passenger. Systems, such as OnStar, have made some headway into this market in the past; however, the analytics and connection to other vehicles and infrastructure was not included in the service offering.[64] DSRC will provide 911 public safety-answering points with far more data than is available today at the time a request for help is received.

Activation of 911 services by a connected vehicle will not only transfer the location of the caller but will send a wide range of sensory data including voice, video, telematics, and geographic infrastructure information. Live audio and video feeds from inside the vehicle can be transmitted not only to the 911 center but to responding personnel to enable constant communication that begins with the 911 dispatcher, transfer to a responding crew, and then perhaps on to hospital staff. Vehicle damage, speed, gravitational force (important for victims of traumatic injuries), and safety systems activation data are packaged and transmitted to help paint a comprehensive picture of the mechanism of injury and are able to be used in not only the emergency treatment of the patient but as part of a definitive care plan implemented by physicians.

Connected vehicle technology can alert nearby emergency and non-emergency vehicles to the occurrence of a collision or medical emergency. Direct emergency vehicle notifications by connected cars can decrease processing and response time in the most critical of responses while permitting other units to be dispatched if the criteria indicate that other, more distant or differently equipped units are most appropriate for the response. Citizen responders will bridge the gap between the occurrence of an emergency and the arrival of professional rescuers by receiving in vehicle notifications to passing vehicles that can stop to provide first aid to those in need. Nearby vehicles can passively be used to stream video images of an accident scene to help paint a picture of criticality, assist in determining the resources that may be needed, or to help in narrowing the location of an ill or injured victim.

Patient medical history and legal documents, such as advance directives, living wills, and do-not-resuscitate orders, are able to be transmitted to responders from

[64] "OnStar," accessed August 25, 2015, https://www.onstar.com/us/en/home.html.

connected infrastructure, devices attached to the IoT, or from the connected vehicle. This critical data can be wirelessly transferred to patient care records, EMS personnel on the scene, the awaiting hospital staff, insurance services, etc. The same mechanism will issue alerts to predetermined friends, family, or employers that an accident has occurred and then transmit any predetermined information to an authorized electronic distribution list.

3. Response

Responding to the scene of an emergency is a risky task not only because of the need to navigate around traffic and the hazards found on the scene often bypassing red lights, standard traffic control systems, and other drivers, but the need to find a person in distress quickly by mapping a route to the emergency scene that can take valuable time away from the response if an address cannot be located quickly. The mapping and routing technology available today has greatly improved the way that responders are able to find an address quickly and then navigate using GPS/AVL. As was discussed in the previous chapter, traffic signal preemption devices have also made a difference by clearing the roadway in the intended direction of travel of the emergency vehicle using line-of-sight transmitters and receivers. The solutions of tomorrow will link existing technologies with the infrastructure provided by connected vehicles and the built environment to reduce EMS response time.[65]

Using vehicle location systems and identification of destination address, response pathways will be created upon receipt of call. The response will not simply provide a map and routing instructions, but will move the community around the responder to make for a safer and more efficient response to the emergency.[66] An early component of V2V DSRC is the ability for a driver to receive emergency vehicle approach information on display screens and through audible alerts. As DSRC and V2V communications improve, the vehicle can be automatically instructed to pull to the side and stop eliminating traffic for responders. Since vehicles are connected to each other wirelessly, an approaching

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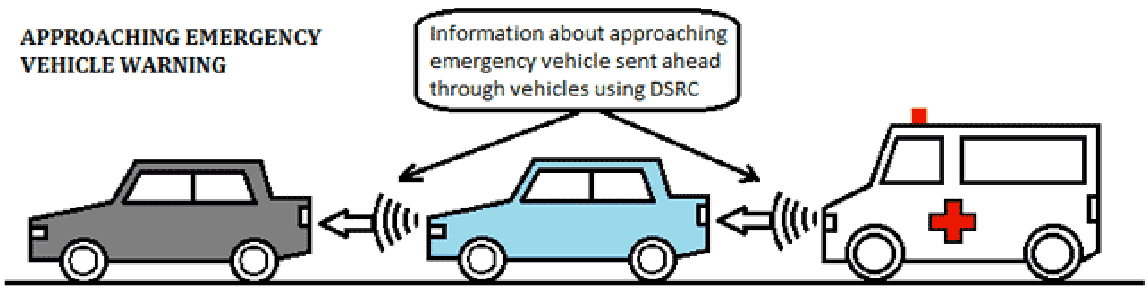
[65] Lambert and Meyer, “New and Fringe Residential Development and Emergency Medical Services Response Times in the United States,” 115–124.

[66] Ho, “Integrating Automobile Multiple Intelligent Warning Systems: Performance and Policy Implications,”

emergency vehicle alert can bounce from vehicle to vehicle, pushing the message further away to enable earlier notification to drivers who may not be able to see or hear lights and sirens (Figure 13). Technologies supported by vehicle to infrastructure, such as radar, will be able to find accident scenes and victims in low visibility conditions including darkness, fog, rain, and snow. The Panasonic Corporation continues to develop automotive millimeter-wave radar technology for just this purpose and completed beta testing in 2013.[67]

Figure 13. Dedicated Short-Range Communication: Emergency Services and Linked Passenger Vehicles



Source: "Dedicated Short Range Communications," accessed August 23, 2015, http://www.cvel.clemson.edu/auto/systems/dsrc.html.

Standardized messaging can be sent to vehicles or electronic signage near roadways that provides important information for drivers when encountering an accident scene. For example, a message can instruct drivers to pull to the furthest lane around the incident, turn off air conditioning and vents if a chemical is present, provide real-time detour information, and other safety messaging. The next generations of systems messaging will simply move vehicles to further lanes, automatically turn off air conditioning and vents, and ask drivers which detour they wish to take.

DSRC will enable roadways to be cleared in advance of responding emergency services personnel. Today, localized transmitters and sensors offer the ability to change traffic signals or preempt trains, gates, and other infrastructure but have limited

[67] Panasonic Corporation, *Panasonic Advances Automotive Millimeter-Wave Radar Technology to Detect Pedestrians and Vehicles in Low Visibility Conditions*.

capabilities. DSRC enables the anticipated response path of the emergency vehicle to be manipulated upon receipt of the call by moving traffic far in advance of an anticipated interaction with an emergency vehicle. Today, a single traffic light can be triggered, but DSRC connected infrastructure and vehicles will be able to synchronize traffic flow to keep intersections and roadways clear, decrease intersection blockage, traffic congestion, and limit the need for emergency responders to drive through red lights, travel at faster speeds, and on the opposite side of traffic flow.

Vehicle grouping is a component of connected vehicle technology that "packs" traveling vehicles by speed, intended destination, or purpose to make the use of roadways more efficient. Packing facilitates prioritization in regard to available lanes, safe speeds, and utility. Using this technology, connected vehicles may be issued a wireless command to pack when an emergency vehicle approaches by placing connected vehicles in a lane that will permit the emergency responder to pass without needing to use emergency lights and sirens.

Emergency lights and sirens placed on emergency vehicles have been a staple of public safety vehicles for generations. The intent of the lights and sirens is to make others aware of a stopped or approaching emergency vehicle so that drivers may yield the roadway for their passage; however, their use also causes panic in some drivers and calls public attention to the emergency vehicle when unnecessary. In the future, emergency vehicles will be able to travel to emergency scenes without displaying emergency lights or the use of an audible siren except in limited cases. In addition to connected in-vehicle warnings and messaging already discussed, "sirens" may be activated within each connected vehicle that has not responded to messaging advising the driver to pull over to eliminate the need to disrupt routine business and travel. A silent but expedient response will benefit the patient, the public, and the responders by making the response and transport portion of emergency response less chaotic.

4. On-Scene Operations

In today's world, emergency responders must interact with an incident—such as a traffic collision—at the location where it has occurred. However, in the future, emergency responders, or perhaps even the 911-dispatch center, will be able to move the scene of an accident to a location that is safer for the patient and the responder. If a vehicle that has been involved in a collision is still able to move, it can be remotely driven to an adjacent parking lot, off the roadway, field, etc. Moving the incident itself protects the patient, responder, and other bystanders from further injury from being struck by other vehicles. If a vehicle is not able to be driven, a wireless perimeter can be activated that automatically surrounds the scene, denying access to approaching connected vehicles and creating a safe place to work for responders, and thereby, reducing physical and emotional stress. Cottrell and Barton in their publication, “The Role of Automation in Reducing Stress and Negative Affect while Driving,” detail how eliminating routine tasks that occupy a driver’s mind can assist in reducing the stress on the body to enable the operator to focus on more critical tasks, a necessity for emergency response personnel.[68]

Audio and video cameras that collect data from connected cars or the built environment can be activated remotely in advance of arrival on the scene to provide important incident details to responders. Cameras are a basic component of new vehicles today for services, such as parking assist and backing safety, and will be used increasingly in connected and AV operations, which rely on a series of standard, as well as radar-based cameras. After arrival on the scene, these cameras can provide real time data to emergency commanders and be used for quality assurance and improvement while the incident is still in progress. Personnel can be equipped with body cameras that stream events as they are occurring, and transmit information back to command posts, medical control, or other locations. Placement of cameras on individuals connected to secure connections will facilitate a better understanding of situational awareness and enable an individual to serve as a “scout” collecting important details used for quality review and perhaps investigation by other partners.

[68] Cottrell and Barton, “The Role of Automation in Reducing Stress and Negative Affect while Driving,” 53–68.

5. Patient Transportation

The application of DSRC benefits the patient transportation phase in much the same way as in the response and scene operations discussed earlier, specifically, mapping and routing, clearing roadways to permit a more expedient and safe transport, emergency messaging to other drivers, and collecting data for quality improvement purposes. In the case of an ambulance transporting a patient to the hospital, unlike the response phase where two personnel are able to assist in navigation and safety monitoring, only the ambulance operator is driving the ambulance when it is traveling from the scene to the hospital as the other EMT or paramedic provide care to the patient. Additional benefits of DSRC in the transportation phase include additional connected vehicle controls and transmission of critical patient care data.

Similar to the response phase, the public often becomes alarmed at the presence of an emergency vehicle traveling with the use of emergency lights and sirens and may panic, and thus, make unsafe and unexpected maneuvers endangering others. Illegal ambulance following is a chronic problem that occurs when friends or family members of a patient being transported follow an ambulance operating with emergency lights and sirens including running red lights, speeding, and perhaps driving on the opposite side of the road. It is often hard for the ambulance operator to determine easily that a vehicle is following because the vehicle often is hidden in the blind spots directly behind the ambulance, while the operator is focusing on the roadway in front and to the sides, is communicating with dispatch, and operating the vehicle in emergency driving conditions.

When a following vehicle is identified today, the ambulance operator’s only options are to stop the emergency transport and continue without using emergency lights and siren, or to stop and then advise the “follower” to not follow them and to follow all traffic laws. Both options are far less than ideal and unnecessarily increase transport time from the scene of an emergency to the hospital. Connect vehicle technology will enable a progressive problem resolution policy by first sending an alert to the ambulance operator advising that a vehicle is traveling behind them as detected by radar and cameras core to connected vehicle operations.[69] This alert can then activate warning systems within the following vehicle directing them to stop following and provide a canned audible or text message that could include directions to the hospital, references to applicable driving law, or any other appropriate information. If the following vehicle fails to comply, the ambulance operator or automatic trigger can cause the vehicle to take control over the driver and safely pull the vehicle to the side and place it in the park position.

Any number of algorithms can be associated with these actions including a "time out" during which time the vehicle remains disabled for a period of time, speed governors are applied, as well as law enforcement notifications, or the connected vehicle is permitted to navigate itself to the hospital. Intentional offenders including those who use emergency vehicle following as a way to beat traffic are easily identified and can be cited effectively since a full set of infrastructure and connected vehicle data is collected. This data would offer proof of violations or aid the accused following driver if they were in fact not responsible for a violation.

Time is essential in not only saving lives but by reducing damage caused by conditions that include heart attacks and strokes. The faster emergency medical responders can arrive on the scene, stabilize and transport patient to a hospital, and then receive definitive medical care by specialized surgeons, the better chances the patient has for a positive outcome. EMS systems across the nation have implemented many advanced procedures that involve the collection of patient care data from the patient before arrival at the hospital. Data is collected and then transmitted to hospital but is limited to episodic occurrences rather than continuous and real or near-real time. The robust wireless platform used to support DSRC enables more data to be streamed faster and permits more real-time patient care information to be collected and transmitted to awaiting hospital staff, such as cardiac and vital sign monitors information. Secure linkages permit emergency department or specialized hospital personnel to "log on" to an active EMS event occurring in the field and monitor the patient as treatment is being

[69] Shin Kato et al., "Vehicle Control Algorithms for Cooperative Driving with Automated Vehicles and Intervehicle Communications," *Intelligent Transportation Systems, IEEE Transactions on* 3, no. 3 (2002): 155–161.

performed by EMS providers. The use of such devices and linkages enables field providers to consult in real-time with physicians or other specialized providers when the need arises.[70]

C. AUTONOMOUS EMS VEHICLES

Little doubt exists that in the future EMS will be heavy users of AVs, including possibly driverless support units and even driverless ambulances.[71] The benefit of AVs is the ability to connect various systems together to improve the value of each exponentially and to realize new benefits through interconnected systems to improve effectiveness and efficiency.[72] EMS organizations must enter the game early in regard to DSRC, as has discussed earlier in this chapter. However, early implementation of AS may be dangerous to responders and the public due to the unique characteristics of emergency response. Once the consumer use of driverless vehicles matures, then it may be appropriate for emergency vehicles to consider driverless ambulances and support vehicles.

The logical first entry into the use of AV by EMS is with supply and support units. Using integrated and connected systems that constantly assess supply levels, resupply orders can be generated and then automatically filled at warehouse locations. The restock is then able to be delivered by a driver-less supply vehicle that makes scheduled stops at various locations to drop-off needed items. Resupply could occur in the middle of the night by making the best use of open roadways and making deliveries while EMS personnel are responding to calls or sleeping during the late night hours.

Driverless multicausality/disaster incident supply units can be dispatched by the incident commander in the field using wireless connected systems to eliminate the need to allocate human resources to simple transportation operation functions. Multicausality/incident supply units stocked with medical supplies that are generally able to service 50 or more patients including intravenous medications, splints, spinal

[70] Epler and Zimmer, "Intelligent Medical Systems for Aerospace Emergency Medical Services," 1–6.

[71] Fong, Thorpe, and Baur, "Advanced Interfaces for Vehicle Teleoperation: Collaborative Control, Sensor Fusion Displays, and Remote Driving Tools," 77–85.

[72] Anderson, Kalra, and Stanley, *Autonomous Vehicle Technology: A Guide for Policymakers*.

immobilization boards, and bandaging materials. Similar to the remote dispatch of autonomous ambulances, multicasualty/disaster units can be deployed throughout a jurisdiction and activated only when needed.

The purpose of EMS is to provide emergency medical care to those suffering from illness or injury prior to arrival at a hospital emergency department. To be able to provide the services intended, EMS providers must drive to the scene of an emergency and then drive the patient to the hospital. Automation of a portion or even all aspects of vehicle operation will make EMS more efficient by automating some tasks and permitting others to be realigned and prioritized to benefit the patient and responder.

In many EMS systems today, an ambulance accompanies other first responder vehicles to the scene of the medical emergency in case the patient requires transport to a hospital emergency department. In the future, ambulance may be able to be autonomously connected to first responder units as needed, and thus, eliminate the need for a designated ambulance operator. The ambulance would accompany the first responder unit that could be any type of vehicle including a police car, fire engine, or EMS first response unit much the same way as if the ambulance were a connected trailer. More than one ambulance could be attached based on the needs of an incident. In the event that a patient does require transport to the hospital, personnel from the first response unit could then manually drive the ambulance to the hospital along with a patient care provider. Such a model would require a significant restructuring of personnel deployment and dispatch practices, but could prove beneficial from a system management perspective.

Future use of this concept will benefit volunteer EMS organizations. As AVT matures, driverless ambulances can be dispatched directly to the scene while volunteer responders provide care at the patient’s side. In cases in which it is difficult to recruit and deploy EMS services, the single EMS responder could provide patient care in the ambulance while the unit autonomously drivers the care provider and patient to the hospital. The use of on board connected systems can automatically alert the hospital of the pending arrival including sending various patient care data elements seamlessly when completed by the EMS responder.

The on-demand or elective ability to make an ambulance autonomous provides promising benefits for situations where a patient is located in an unsafe environment. In such cases, responders will often have to wait until the hazard is eliminated before making contact with a patient in need of medical care. Examples include hazardous materials incidents, shootings and stabbings, and other violent events. Autonomous ambulances could be placed into “driverless mode” and then respond within the “hot zone” to extract the patient, as long as they are able to enter the ambulance on their own. Specialized ambulances can be outfitted to operate in these environments that may be fortified with armor for active shooter situations, contain specialized hazardous materials sampling sensors, as well as integrated patient decontamination systems.

Ambulance coverage could be greatly improved by placing autonomous ambulances throughout a community that would remain “out of service” until the need for activation occurs. As call volume increases or large events occur, these units can be activated and the dispatched to the scene of an emergency where EMS providers are caring for the ill or injured. An autonomous ready reserve ambulance fleet can be summoned to replace a disabled ambulance that may have experienced a mechanical failure, becomes blocked due to traffic or other impassable barrier, or simply to replace an in-service ambulance in need of fuel or routine servicing.

D. CHAPTER SUMMARY

The adoption of AS use in EMS has a long way to go before it hits the streets of America in the form of a driverless ambulance or supply unit. However, AS, such as those that may be connected through V2V and V2I wireless connections, are currently in use. EMS providers will benefit from understanding the need to leverage sensor devices and analytics that can be used in collaboration with other systems to provide integrated and exponential efficiencies in service delivery.

EMS provider organizations have the opportunity to get involved in these emerging technologies now so that they can be developed to support EMS needs rather than cause hurdles in the future. EMS will always be significant users of technology, not only in providing direct patient care but also in all aspects of the infrastructure required to deliver this service. The critical services that impact the lives of those who use EMS must be made better by technology rather than suffer from lack of integration that serves responders and patients well.

The use of AS is not without risk. The technology is new, will be wrought with “bugs,” and will need further development and fixes for years to come. The ability to corrupt, either intentionally or unintentionally, can have catastrophic impacts to the public safety system. A technology dependent delivery system is vulnerable either by disabling services or making the technology work against responders, the machines can become the “bad actor” of the future with an almost infinite wireless reach. The next chapter will explore these concerns in greater detail and provide insight into how AS are a threat to homeland security.

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VI. HOMELAND SECURITY CONSIDERATIONS

AS are technological systems or processes that either support or replace human decision making, which means that corruption of such systems can cause catastrophic and escalating failures that threaten security of the homeland. The interconnected nature of AS combined with their use in public safety and critical infrastructure makes them susceptible to either intentional or unintentional disruption. Most systems fail at some point; however, they can be properly engineered to default automatically to contingency operations or isolate failures in a way that interconnected systems may continue to function with limited interruption to the service performed. The lack of foresight by executive leadership of EMS provider organizations is another potential threat to homeland security related to the use of AS. Organizations unaware of emerging technologies will fail to plan for disruptions properly or to embrace technologies that can improve the security of the operations, as well as provide redundant systems that can take over during the loss of such a technology failure. The widespread electrical power failure in the northeast portion of the United States in 2003 provides an example of when adequate redundancies were not in place that resulted in cascading system failures.[73] This chapter will discuss intentional and non-intentional disruption possibilities related to AS.

A. UNINTENTIONAL DISRUPTION

Gordon Graham is veteran of public safety service who has worked as a law enforcement officer for the California Highway Patrol (CHP) for over 30 years, is an attorney, and has been a recognized expert in the area of risk management for decades with a focus on public safety organizations. Graham believes that "predictable is preventable" and that public safety managers are responsible to plan properly today to avoid what could become a catastrophic failure in the future.[74] He believes that much of

[73] Chaamala Klinger, Owen Landeg, and Virginia Murray, "Power Outages, Extreme Events and Health: A Systematic Review of the Literature from 2011–2012," PLOS Currents Disasters, January 2, 2015, http://currents.plos.org/disasters/article/power-outages-extreme-events-and-health-a-systematic-review-of-the-literature-from-2011-2012/.

[74] Gordon Graham, "Lexipol," accessed August 30, 2015, http://www.lexipol.com/.

what will go wrong in the future is known. Yet, organizations fail to recognize potential failures properly and engineer solutions to mitigate problems before they arise.[75] An example is that police patrol cars rely on the use of tires on the vehicle; it is predictable that a tire will fail. Therefore, a system needs to be in place that permits the rapid replacement of damaged tires quickly. The good news is that in regard to AS, much of what can go wrong is predictable. The interconnections and the myriad of technological linkages offer a starting point for risk management planning in regard to the IoT and AV.

Unintentional disruption will cause failures of AS that will result in complications for EMS providers. Technological failures should be expected as should human operator errors, as is common with almost any system-of-systems. The impact of the majority of these disruptions is likely to be small, or perhaps, even viewed as minor inconveniences for most users, as technology providers are highly responsive to variances to preserve their reputations in a highly competitive market.[76] In technology-based businesses, rapid customer support is essential to not only remedy problems that should arise but to keep the consumer engaged in expanding the use of the providers' technological offerings.[77]

1. Internet of Things

The management and protection of sensitive data is essential in the ever-growing connected environment. Sensor technologies are becoming smaller, more diverse, and specialized while collecting more data than has ever been complied before. Thus, data identifying the interworking of an organization is constantly being documented, archived, potentially released for public access and is susceptible to loss and or exploitation. Most modern day EMS organizations have an information technology department that focuses on the very basic operation of information systems within their organization, as well as overseeing data security. Understanding that most emergency medical service provider organizations are staffed very lean, personnel tasked to information technology

[75] Ibid.

[76] Kaj Storbacka, Tore Strandvik, and Christian Grönroos, "Managing Customer Relationships for Profit: The Dynamics of Relationship Quality," *International Journal of Service Industry Management* 5, no. 5 (1994): 21–38.

[77] Ibid.

responsibilities may be an ancillary job. In other words, IT security may not be the key priority and IT tasks may complete with other operational needs, such as responding to emergencies, vehicle supply, or other administrative duties. The level of data system oversight and protection will need to increase to protect not only patient and responder information, but also the details related to all operations of the system including vehicle movement, driver actions, telemetry transmissions, etc. Developing appropriate data security will represent a challenge, as securing systems will need to be balanced with the operational needs of EMS providers. The public is likely to become wary of using EMS if they fear that their information could be inappropriately shared should a data breech occur. Adequate protections must be in place with several levels of redundancy for each independent and connected system used.

All AS and technologies require power for operation; therefore, any sustained loss of adequate power supply will have an impact on the ability of the technologies to provide the benefits anticipated. Battery systems will provide short-term power supply to most systems, but will not be able to fill the energy needs for more than a few hours at the most. Longer term power disruptions, such as those caused by earthquakes, weather events, or other disaster situations, will cause many automated systems to fail and users will be required to change operational practices and rely on manual processes that may have become unfamiliar due to inconsistent application, are time consuming, and cumbersome.

Untrained or unsophisticated users can cause systems to be underused or used incorrectly. Fortunately, the widespread development and implementation of AVs in daily life is years away that provides adequate time to develop appropriate training, exercises, and prepare the human resource component of EMS providers. During this time, new systems that use the IoT, will help to stair-step further integration of technology at the same time that AS development continues to take shape as a reliable technology. The incremental growth of systems combined with the average American's increased reliance on technology in almost all aspects of daily life will assist in successful assimilation and implementation of AS. However, traditional non-technology based practices will need to be exercised frequently should a failure in the system occur so that EMS personnel can continue critical work with limited disruption.

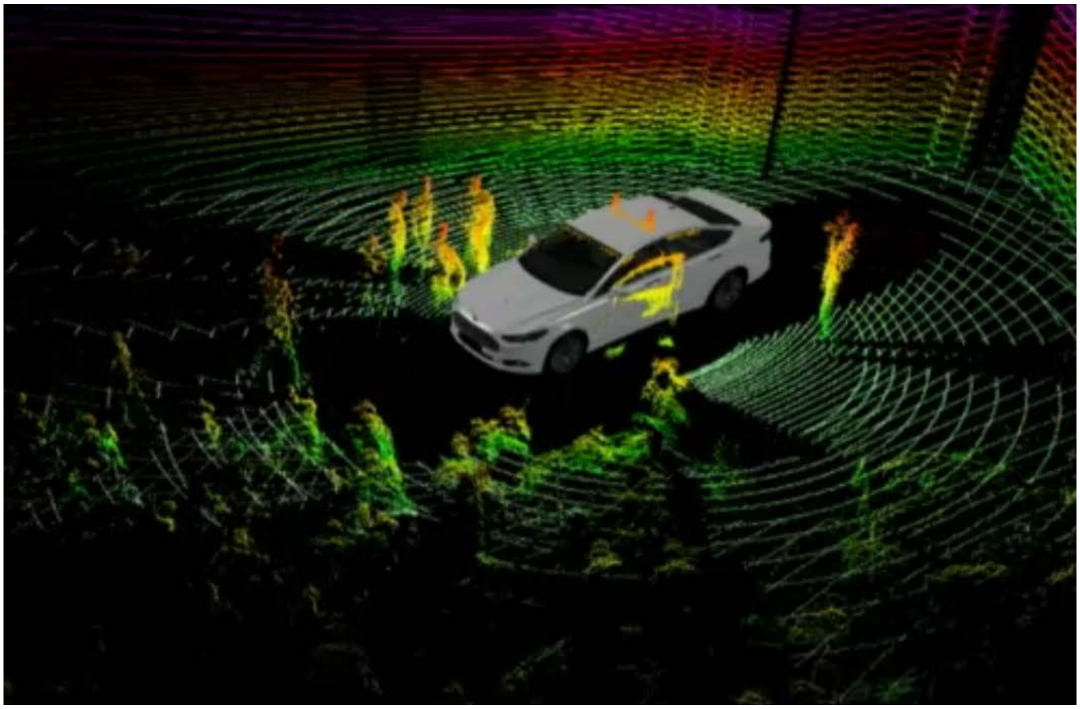
2. Autonomous Vehicles

For vehicles to become autonomous, they must be connected to the infrastructure through various systems that provide onboard artificial intelligence systems with data to make appropriate decisions. AVs use a technology called light detection and ranging (LIDAR), which uses laser technology to bounce light off objects to determine location, speed, and distance.[78] LIDAR is what keeps vehicles from crashing into other vehicles, people, or infrastructure (Figure 14). The V2V and V2I detection system is at the core of connected vehicle communications. In addition, GPS provides location information to onboard data systems that provide for the automatic navigation of vehicles.[79] In the event of a LIDAR or GPS failure, connected vehicles will not uncontrollably continue to operate; they will come to a stop as a safety mechanism. Unintentional failures in these systems would cause significant disruptions in routine EMS operations by impacting the roadways on which these vehicles normally operate creating traffic, road blockages, and hazards.

[78] Michelle Birdsall, “Google and ITE: The Road Ahead for Self-Driving Cars,” *Institute of Transportation Engineers. ITE Journal* 84, no. 5 (May 2014): 36–39.

[79] Ibid.

Figure 14. Light Detection and Ranging (LIDAR)

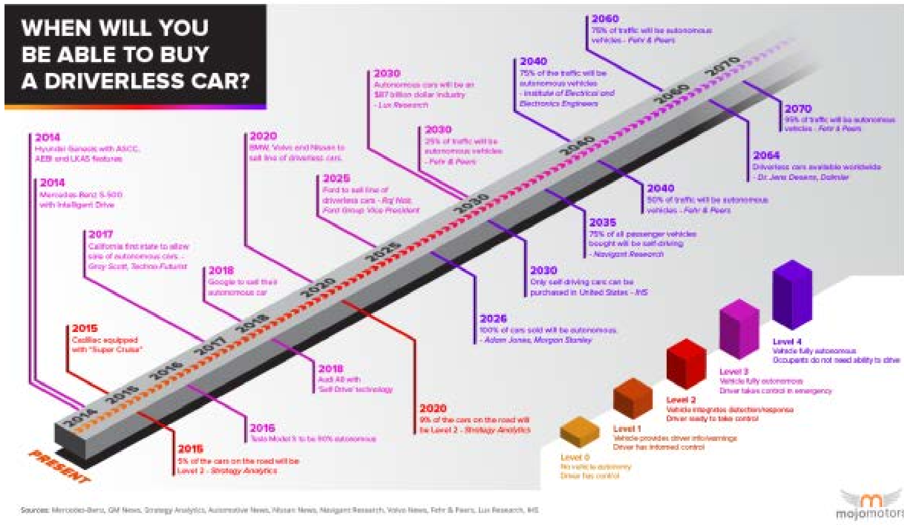


Source: Melissa Riofrio, "Spiked with LIDAR Sensors, Ford Research Car Tracks Objects and Creates 3D Maps," TechHive, December 12, 2013, http://www.techhive.com/article/2079570/spiked-with-lidar-sensors-ford-research-car-tracks-objects-and-creates-3d-maps.html.

AVs will not hit the streets on a large scale until they have been proven to be safe and reliable. The amount of road miles, legal oversight, and quality assurance that is part of AV development is significant and will help to minimize uncertainties associated with the technology. New problems and technological concerns will surface as the technology is placed more in the mainstream market; these problems and concerns are generally "known unknowns." The bigger concern are the unknowns that could be of scope and scale that would cause impacts that have not been anticipated through testing or that have not been considered in contingency plans. Unfortunately, the unknowns cannot be planned for with the exception of having all risk mitigation plans in place that contemplate EMS operations during worse case scenarios in which all technology is eliminated.

In the future, non-AVs will represent the hazard for emergency medical responders rather than AVs. In a connected world essentially running its infrastructure on “auto pilot” through millions of sensor devices analyzed using artificial intelligence, a device that interacts with such an environment and is not connected represents a great threat. The failsafe and redundant systems that support AVs to keep them safe and under control will fail to protect vehicles when these systems have been disabled or are simply not present. Public services will be unable to respond to service needs for those not using connected vehicles as timely and as effectively as those that are “networked.” Users of non-AVs may experience a different level of accessibility where they may be restricted from operating in certain areas and may realize a lower level of service. The implementation of laws, as well as affordable AVs, is key in the long-term success of implementation, similar to that of cell phones. Initially high priced and marketed to the business professional or government user, technology costs decreased and enabled widespread adoption by most people decades following its launch. Initially, AVs will be for the affluent and government users before finding a mechanism to make its entry into market at a price point acceptable to the masses. The providers of EMS will be required to interact with a changing public, one that uses AVs as a new and trendy technology, though decades of adjustment including periods of mixed autonomous/non-AV use, to a time where a human-operated vehicle is a rare find (Figure 15).

Figure 15. Autonomous Vehicle Implementation Timeline



Source: Brett Solomon, "I Want to Be a Holdout in the 2070 Fully Autonomous World," Technology Tell, July 20, 2014, http://www.technologytell.com/in-car-tech/9538/want-one-holdouts-2070-fully-autonomous-world/.

B. INTENTIONAL DISRUPTION

The intentional disruption of AS using DSRC, V2V, V2I, and IoT will threaten the provision of EMS. The implementation of AVs will provide a further venue for terrorist activity through the everyday hacker's infiltration of these connected systems with relative ease.[80]

The exact methods by which these various electronic and interconnected systems can be infiltrated and used against the general population and EMS providers is not known; however, the ability to carry out an attack using electronic means is certain. Terrorist organizations, such as Al Qaeda (AQ) and ISIS, have declared their intent to conduct attacks on the United States. The use of technology to further this intent is likely

80 Poulsen, "Hacker Disables More than 100 Cars Remotely,"

and provides a medium that is easily accessible, inexpensive, and has the ability to create great damage, as well as public fear.[81]

Intentional disruption of connected systems can come in many forms and for different purposes. The 2014 cyberattacks on Sony Pictures demonstrated that hacking could be used to cause inconvenience, instill fear, cause financial disruption, and serves as proof that attacks can be successfully implemented with relative ease.[82] The intent of these attacks was not to destroy Sony, but to cause embarrassment and demonstrate that the attacker was capable of infiltrating one of the largest American entertainment businesses in existence. The infiltration of data systems represents the basic foundation of most intentional attacks; in some way, bad actors will gain access to either remote controlled systems, manipulate data, or confuse AS to take actions beneficial to the terrorist. The possibilities are innumerable, bound only by the imagination and by elementary cybersecurity systems that may be in place to help recognize when something may be wrong. Turning systems on themselves or using them exactly as they were intended to be used means that recognizing when they are being used for terrorism or criminal related activity might be hard to identify.

Deliberate infiltration and manipulation of systems used by emergency medical responders can decrease the timeliness and responsiveness of their capability to serve the public during times of emergency need. The amount of interconnected and dependent systems that support EMS providers each day creates a perfect venue for launching an attack regardless of intent, to include probing type attacks by hackers and or criminal manipulation to prevent or slow response times. Systems, such as inventory control, predictive call modeling, vehicle fueling, traffic signal preemption, mapping, call routing, medical telemetry, and communications systems, are relied upon every day. Any disruption in these systems would result in less units being available for emergency

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[81] Bill Gertz, "Al Qaeda Targeting U.S. Infrastructure for Digital 9/11," *The Washington Free Beacon*, July 24, 2014, http://freebeacon.com/national-security/al-qaeda-targeting-u-s-infrastructure-for-digital-911/; Graeme Wood, "What ISIS Really Wants," *The Atlantic*, March 2015, http://www.theatlantic.com/magazine/archive/2015/03/what-isis-really-wants/384980/.

[82] Michael Cieply and Brooks Barnes, "Sony Cyberattack, First a Nuisance, Swiftly Grew Into a Firestorm," *The New York Times*. December 30, 2014, http://www.nytimes.com/2014/12/31/business/media/sony-attack-first-a-nuisance-swiftly-grew-into-a-firestorm-.html?_r=0.

response. Depending on the scope and nature of an attack, entire service areas could be eliminated by severing communication pathways, alerting system corruption, or causing system shut down through data confusion.

Public safety organizations, including EMS, collect sensitive and confidential data that assist in providing faster and more efficient service to the public. Data includes stored gate and security codes, the travel history of emergency vehicles, and detailed ambulance deployment plans. In the event that an adversary collects this data, it can be used to plan attacks to gain access, target attacks in areas in which EMS resources are limited, or use EMS systems as unknown accomplices. An example may be using inaccurate emergency call data that would be processed by predictive modeling systems resulting in moving ambulances away from an intended target area that would then result in a delay in providing medical and transportation. Ambulances that transmit security-coded information could be commandeered and then used to penetrate hardened perimeters to provide access to those wishing to cause damage to critical infrastructure, such as 911 communication centers, public service infrastructure, utilities, and transportation hubs.

The ability to control vehicles remotely provides an excellent method for launching highly effective, coordinated, and grandiose attacks with EMS and public safety vehicles as the primary weapon.[83] Suicide bombing has been a preferred method attack by many Islamic extremist organizations primarily due to ease of use and the ability to cause a significant amount of damage. Given the access provided to EMS vehicles to secured areas, especially ambulances, using them as remote controlled bombs would cause significant damage. In 1995, AQ had planned to detonate 11 passenger airliners simultaneously over the ocean in an elaborate attack intended to show the power of AQ and instill fear in the western world.[84] Due to their size and ability to freely move

[83] Lucas Mearian, "Hacker: Hundreds of Thousands of Vehicles Are at Risk for Attack," Computerworld.Com, July 23, 2015, http://www.computerworld.com/article/2951489/telematics/hacker-hundreds-of-thousands-of-vehicles-are-at-risk-of-attack.html.

[84] Christopher S. Wren, "Bomb Trial Jurors Say Panel Had No Doubts," *The New York Times*, September 9, 1996, http://www.nytimes.com/1996/09/09/nyregion/bomb-trial-jurors-say-panel-had-no-doubts.html.

in most environments, outfitting multiple autonomous ambulances with bombs and then remotely directing them to designated targets prior to detonation would provide not only a grand attack but would deliver catastrophic results in the not so distant future.

On March 27, 2002, an ambulance operating in Israel’s West Bank was discovered to be carrying explosives when the vehicle was stopped as part of a routine checkpoint inspection. The explosives were hidden under the gurney designed to transport patients in need of critical medical care from the field to the hospital.[85] As a result, the Israel Ministry of Foreign Affairs was able to use the incident to illustrate not only the ability to use an ambulance for nefarious purposes but to recognize that ambulance personnel and their security authorizations provide the opportunity to inflict harm to others based on their ability to access secured locations, such as hospitals, military facilities, and government centers.[86]

According to the 911 Commission Report, the terrorists responsible for the September 11, 2001, attacks on the United States leveraged existing infrastructure to use heavily fueled passenger airliners as bombs rather than attempting to manufacturer and then successfully place and detonate explosive devices on the aircraft.[87] An attack could be launched if various AV control systems on ambulances are hacked and then remotely controlled. It would not be necessary to place explosive devices within the ambulances, as the vehicle itself can be used to cause casualties either by striking people, using the vehicle to strike an explosive source, or cause the release of a hazardous chemical or substance.

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[85] Anti-Defamation League, “Explosives Found in Palestinian Ambulance,” April 1, 2002, http://archive.adl.org/israel/israel_explosives.html.

[86] Israel Ministry of Foreign Affairs, “Palestinian Misuse of Medical Services and Ambulances for Terrorist Activities,” October 13, 2014, http://www.mfa.gov.il/mfa/aboutisrael/state/law/pages/palestinian%20misuse%20of%20medical%20services%20and%20ambulances%20for%20terrorist%20activities%2013-oct-2004.aspx.

[87] Thomas H. Kean and Lee Hamilton, *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks upon the United States* (Washington, DC: National Commission on Terrorist Attacks upon the United States, 2004).

C. PREVENTATIVE INVESTMENT AND COLLABORATION

The job of keeping EMS systems secure from terrorist activity is a significant undertaking and requires that EMS organizations invest in collaborative efforts to harden vulnerabilities, recognize potential areas where the EMS system could be compromised, and in the sharing of data that could help in planning or may reveal indicators of potential terrorist activity. EMS systems are complex and include a large range of partner organizations, such as dispatch centers, hospitals, fire departments, law enforcement agencies, and the public. These organizations must have a venue to share information and then have opportunities to support each other through mutual aid agreements or memorandums of understanding where resources can be shared should an intentional or unintentional disruption of public safety services occur. Early investments in partnerships and collaborative efforts will help to make EMS more resilient, and thereby, provide necessary redundancies to support response operations during any victim surge event including acts of terrorism.

D. CHAPTER SUMMARY

The homeland security concerns related to the use of AS use in EMS is an emergent field worthy of study. Until AS mature and begin to enter the consumer market, the ability to analyze specific concerns will be difficult. Today's homeland security professionals can evaluate each electronic system in place within their EMS organization and identify ways to operate should it fail or be corrupted, and implement continuity of operations plans that help reduce the likelihood of systems failure. The role of sensors and the data that they collect are the building blocks of the AS of the future; controlling how data is collected, stored, and used today is an essential first step.

EMS providers should use the next several years to prepare for the inevitable explosion of autonomous technology that will impact everyone's lives in the next decade. Paying attention to the development of technologies with a an eye towards how they may be infiltrated and used to impede the services provided by EMS organizations will be beneficial for the safety of EMS responders in the future and for helping to ensure the resilience of essential public safety services.

The past chapters have provided information as to the type of technology that is available today and how it may be integrated into EMS operations. This chapter provided some high-level ideas of how the technology could be used to the detriment of EMS systems. Understanding how these technologies can be corrupted and used against the citizenry is essential. Those who wish to do harm to nations, innocent civilians, and even public safety personnel, will be working diligently to exploit good intentions with their malicious plots to cause disruption, injury, and death. Early analysis and diligent monitoring of evolving technologies is the only way public safety systems can be able to stay on top of future threats, and then develop appropriate countermeasures far in advance of an attack. Although mature autonomous technologies are a bit down the road, awareness and preparedness must start today or the nation will surely fail to protect its people.

VII. CONCLUSION

This thesis has focused on the analysis of what AS are, how they are used in the provision of EMS today, how they may be leveraged in EMS systems in the future, and concerns related to the use of these systems in regard to homeland security. The rapid development of AS, which are technological systems or processes that either support or replace human decision making, will have a significant impact on public safety services, including EMS. Based on analysis conducted, the leveraging of AS technologies will enable emergency medical responders to improve efficiency, reduce cost, and provide greater service to those in need.

Many technologies exist today that will become the framework for future development and growth of AS. New vehicles manufactured in the United States in 2016 will be the first to be equipped with C2C and car-to-infrastructure technologies in advance of the widespread infrastructure that will be needed to support such enhanced communications. The recommendations provided in this chapter are intended to provide EMS system leaders with suggestions that will enable them to monitor and use AS once the technology hits the consumer market in coming years. The good news is that EMS providers have time to educate themselves as to what new technology will mean to the industry and to enter the conversation related to the impacts, both positive and negative, of AS integration in EMS.

A. RECOMMENDATIONS

The following recommendations are made concerning technology, data security and infrastructure, industry leadership and creating a successful EMS organization.

1. Embrace Technology

EMS providers must understand how available technology can support the provision of services and should implement those systems that will improve efficiencies and the services provided to patients. Systems, such as predictive modeling, the use of automated vehicle locator systems supported by global position systems, remote vehicle disruption, Internet and satellite supported information systems, medical technology, and the collection of medical data are available today. EMS systems not using these technologies are arguably behind the curve and not providing state of art care.

It is understandable that the use of many of these systems may be cost prohibitive or are not necessary for the size of the service area for which the EMS organization is responsible. However, the early adoption of systems, such as those described previously will better prepare the organization for future changes, such as self-driving cars, car-to-infrastructure communications (such as changing traffic signals, etc.), and DSRC through the integration of human decision making with AS. The return on investment for these systems will save costs in the long run by enabling organizations to refine response and control costs that could be automated or reduced with leveraged technologies.

2. Data Security and Infrastructure

Every EMS provider is aware of the need to secure data. Federal requirements related to healthcare data collection, billing, and care documentation require the use of electronic data systems and modest data security provisions. Providers will benefit from investing in understanding the depth of data available, understanding how it may be used, and building a strong and redundant data protection infrastructure.

The majority of today's data security needs are based on protecting health care information or adhering to personal identity protection standards as required by local or state laws. Understanding that almost all electronic devices now collect data, it is imperative that organizations understand how wireless communication networks may be used to corrupt various systems and can make an organization susceptible to infiltration.

3. Provide Industry Leadership

C2C communications, car-to-infrastructure communications, and AVs represent future challenges and opportunities for providers of EMS. The world in which EMS and the general public operates will change as a result of these emerging technologies. EMS provider agencies have the opportunity to get involved now by helping to frame how technology may best support EMS operations. If EMS provider organizations and professional industry associations do not get involved, they will be required to conform to systems that will be built without consideration for how new technologies may impact the provision of EMS. Professional organizations will benefit from developing position papers and providing guidance for their members that keep them informed, engaged, and aware of emerging technologies that impact EMS.

Developers of public policy must consider how AS will give priority to emergency medical service provider needs including priority access to data, infrastructure, connected systems, and connected vehicles. While many of the specific details related to these technologies are yet to be developed, policy should simply recognize the existence of these technologies and require that public safety, including EMS, be included in laws, mandates, and guidelines.

4. Position Your Emergency Services Organization for Success

The personal computer was once thought to be an unnecessary tool for non-business applications; obviously, history has demonstrated that personal computing is a cornerstone to our existence. Personal computers in today's world not only take the form of home computers and laptops, but most people wear a mobile computer every day in their Smartphone or tablet. As was presented in the introduction of this thesis, the "flying ambulance" used by Napoleon was a technological advancement in the provision of healthcare that not only helped to save lives but assisted the army in remaining strong by keeping more soldiers on the battlefield. EMS providers must constantly evaluate the services that they provide with an eye towards demonstrating a return on investment for each of these services. The ACA requires that EMS providers demonstrate the need for the services that they have provided to patients to justify receiving payments from federal payers.

Successful, therefore financially stable EMS organizations, will embrace technology as a means to address the threats associated with demonstrating value in the provision of the services that they provide. The use of technology must be in the tool chest of every EMS organization, and strategic planning and long-term budgeting are essential in keeping pace with future mandates and customer service demands. AS offer mechanisms to not only capture data through thousands of sensors but can provide automatic reporting, check-and-balance systems, and automation of costly human workloads.

B. SUMMARY

In summary, if an EMS organization questions the value of AS, consider applying the strengths, weaknesses, opportunities, and threats (SWOT) approach to evaluating the impact of *not* embracing AS. The organization will recognize that weakness and threats will be high, the number of opportunities will be diminished, and the strengths may be nonexistent other than perhaps initially saving some costs and continuing to operate in a familiar fashion that requires little training. A universal SWOT cannot be provided that will address the needs of each organization in regard to the use of AS. However, in evaluating if the organization’s mission is being met and determining if the return on investment is positive, the integration of at least a basic level of AS is necessary. The gradual implementation of AS will provide EMS organizations with at least a basic level of awareness of future technologies and expose providers to potentials for improving efficiency and services.

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