EMERGING ISSUES IN EMS AND 911

Emerging Digital Technologies in Emergency Medical Services: Considerations and Strategies to Strengthen the Continuum of Care

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EXECUTIVE SUMMARY

Study Purpose, Objectives, and Methodology

The last two decades have witnessed an unparalleled technological revolution in digital systems, including the many ways and forms that information can be processed and communicated. These new systems—whether mobile, social, cloud-based, or big-data intensive—are fundamentally affecting industries throughout society. Certainly, important technological and policy developments have occurred over the last decade that will impact the way Emergency Medical Services (EMS) is conceptualized and delivered in the future. This is an opportune time for EMS to engage in its strategic direction; to choose how it will benefit from existing and emerging digital technologies with the aim to achieve, and even surpass, the original information systems vision as presented in the 1996 "EMS Agenda for the Future."

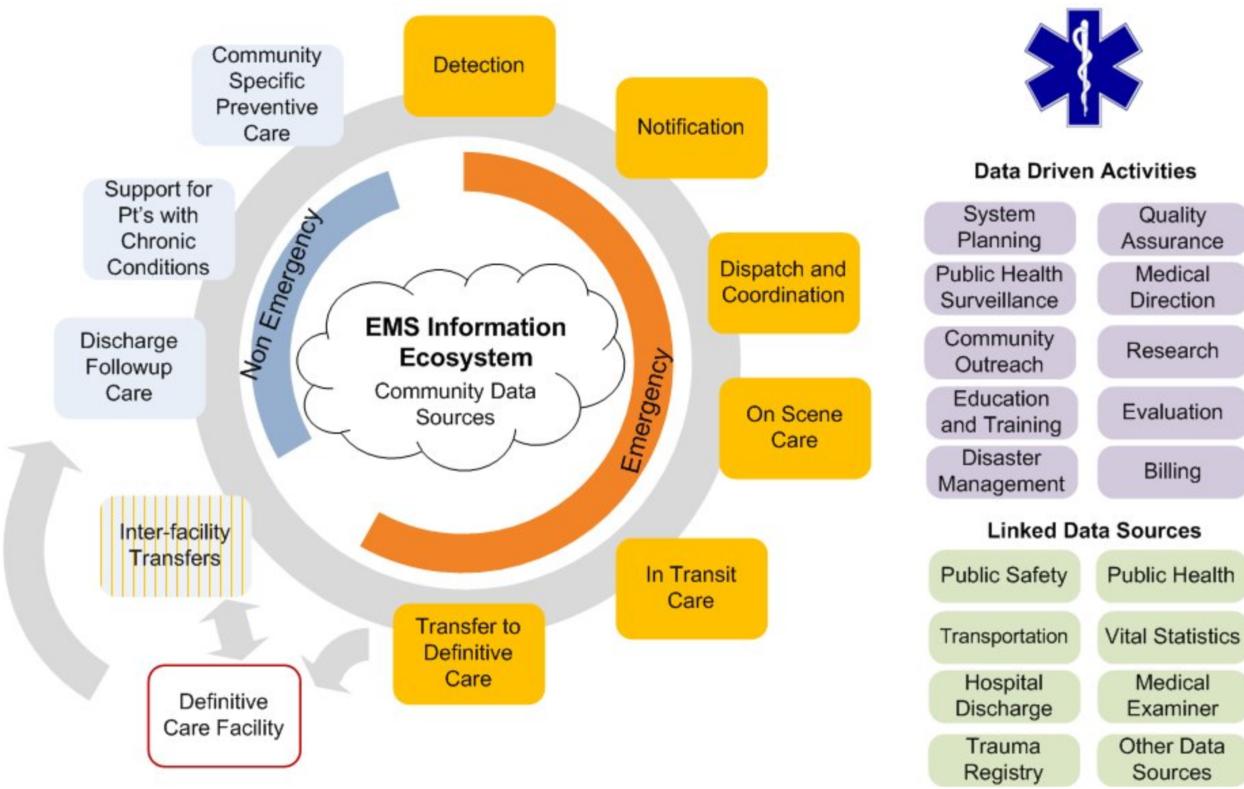
The purpose of this paper is to provide a broad review, analysis, and identification of opportunities for the EMS community to address digital technology developments and offerings. Objectives of this review are to:

- To summarize the overall impact that digital data, medical devices and software applications could have on EMS and their influence on how EMS and 911 systems might operate in the year 2020 and beyond, including the potential for impacting downstream cost savings to the health system and influencing new service opportunities for EMS.
- To synthesize available and emerging digital and mobile technologies and software applications marketed toward the prehospital and 911 environments. What are the common technologies in use today? How are they used? What are the emerging technologies EMS should be aware of?
- To present a model for how these technologies might be used by EMS and 911 systems to improve patient care, systems operations, and performance measurement.
- To investigate how EMS and 911 systems can proactively influence or shape the development of new technologies to enhance their applicability to EMS and 911.
- To identify and analyze mobile and digital technologies from other sectors that show strong potential to improve patient care, training and education, system safety, and operations.
- To present options for how EMS and 911 personnel can evaluate new technologies to assess their clinical and operational contribution to enhancing EMS systems and the delivery of emergency medical care and 911 services.
- To consider policy, legal, organizational, and regulatory challenges that must be addressed before the use of new digital data, medical devices and software applications.
- To educate the EMS and 911 communities about what is possible with emerging technologies and software applications.

These objectives were achieved through a comprehensive review of EMS reports and peer-reviewed articles, complemented by background discussions with 16 subject matter experts. The preliminary findings were presented to the National EMS Advisory Council (NEMSAC), and the final report prepared based on this feedback, and well as feedback from the US Department of Transportation liaison and two expert reviewers.

To help in this assessment, a high level review framework was developed to determine how and where digital technologies might impact operations and clinical care for persons injured in motor vehicle crashes or who have other health emergencies. The framework assimilates a wide range of traditional and emerging EMS activities into a core set of activities, the EMS Continuum of Care (see Figure 1). While the framework is not meant to be comprehensive and inclusive of all possible EMS actions and responsibilities, it provides a common view for discussing technology opportunities and challenges.

Figure 1. EMS Continuum of Care



Key Findings and Implications

Results are organized into an interrelated set of findings summarizing the impact of digital technologies on EMS. Key findings are:

- Digital technologies have caught up with, and in some cases surpassed, technology expectations described in the 1996 "EMS Agenda for the Future."
- The original information systems section of the "EMS Agenda for the Future" provided 5 goals that, 13 years later, could be enhanced by providing additional specificity and inclusivity of data, such as *how* data can be collected, analyzed, shared, and integrated across EMS organizations and operations.
- A common, integrated view of the role of EMS – the EMS Continuum of Care – provides a foundation for the wide-scale assessment and design of technologies that support its mission, goals, and objectives.

- Technology developments are occurring across the EMS Continuum of Care; however, important gaps remain in their implementation, such as in assisting with monitoring high risk patients, early detection of clinical emergencies, assisting EMS personnel with preparation for care, and timely information sharing across prehospital and hospital systems.
- Existing business, policy, and funding models limit the role of EMS and its use of technologies across the emergency related portions of the EMS Continuum of Care, including incentives for technology adoption and use.
- Using technology to strengthen the EMS Continuum of Care can lead to operational and health benefits, although such impacts have yet to be definitively assessed.
- EMS and its use of technology has a strong relationship with the transportation sector, both in terms of addressing motor vehicle crashes as well as its unique use of the transportation system.
- A new generation of skills is required to design, implement, and manage technologies across the EMS Continuum of Care to derive operational and clinical value for EMS systems.

Based on these key findings, strategies are outlined that the EMS community could consider to further define, analyze, test, and build a modern digital infrastructure for EMS. Possible strategies include:

- Define “Meaningful Use” of EMS information technology (IT), including how EMS organizations can be most appropriately incentivized to meet EMS IT “Meaningful Use” definitions.
- Support existing and emerging EMS delivery models with the selection, design and implementation of IT solutions. EMS delivery models to consider may include those that support preventive and community care; prehospital emergency and nonemergency transport; and hospital, and post hospital patient follow-up and care activities. Technology solutions may need to be customized to key health conditions of concern to local health providers (e.g. cardiac, diabetes).
- Strengthen prehospital to hospital communication - engaging the hospital community to define, on a broad scale, what prehospital information they want to see, how they want to see it, and when they want to see it for each type of care episode.
- Include EMS in transportation analysis, research, and reporting. One key strategy may be to provide an annual EMS transportation report that summarizes EMS utilization and performance, including EMS vehicle miles traveled and safety statistics.
- Create new technology-centric EMS education and training modalities. This may include devising formal educational curricula for integrating technology use into care practices; professional forums for sharing technology best practices and peer-to-peer learning; and developing mobile, video based learning modules for just-in-time training.
- Support applied research of EMS information technology to discover new digital solutions and their associated operational and health benefits/risks.
- Investigate Big Data intelligence opportunities, supporting the creation of EMS test sites with identified traditional and non-traditional data elements, and utilizing these for concept testing and algorithm development.
- Analyze new sources and uses for device and sensor information across the EMS Continuum of Care, including the impacts of consumer and practitioner mobile computing on EMS operations and patient care.
- Actively support ongoing open standards and protocol development. This may include forming an EMS “open data” forum; actively supporting ongoing development of mobile app and device

standards; and defining how both consumer and practitioner mobile apps and devices can most effectively be integrated, validated, and utilized in EMS.

Taken together, these findings, considerations, and strategies suggest that there is considerable value in launching a new generation—a new "Agenda" of EMS technology research, testing, and deployment to support enhanced EMS performance across the full EMS Continuum of Care.

INTRODUCTION

EMS and Technology

Emergency Medical Services (EMS) has long been connected by technology; indeed the 911 telephone system and the two-way radio were a cornerstone in the development of the first coordinated notification, dispatch and response systems. In the 1966 white paper "Accidental Death and Disability: The Neglected Disease of Modern Society," communications technologies were considered an integral part of EMS.(1) Forward thinking EMS reports since that time have called for improvements in the way EMS communicates and how information is used. In the 1996 report "EMS Agenda for the Future,"(2) Dr. Daniel W. Spaite noted the following:

> "Finding desperately needed answers to many important questions in EMS are hopeless without the development of new ways to collect, link, and analyze valid, meaningful information. This is the very foundation of the future of EMS!"

Today, this statement is as true as ever. The last two decades have witnessed an unparalleled technological revolution in digital systems, including the many ways and forms that information can be processed, stored and communicated. These new systems—whether mobile, social, cloud-based, or big-data intensive—are fundamentally affecting industries throughout society. There is no way to know for sure how EMS would have been structured politically, organizationally, or financially had the robust, wireless broadband networks, powerful mobile computing capabilities, and deep data analytical capabilities of today existed when establishing EMS systems decades ago. Rather, we are left to reevaluate, revise, redesign, and retrofit EMS as technologies continue to advance. Lack of action in the face of uncertainty will adversely impact EMS' ability to adapt to the changing role of digital technology.

Certainly, important technological and policy developments have occurred over the last decade that will impact the way EMS is conceptualized and delivered in the future. This is an opportune time for EMS to play a significant role in achieving and surpassing the original information systems vision as presented in the 1996 "EMS Agenda for the Future." EMS leaders must now address how technology will allow EMS to take advantage of the available opportunities.

Purpose, Scope and Objectives

The purpose of this paper is to provide a broad review, analysis, and identification of opportunities for the EMS community to address digital technology developments. Objectives of this review include:

- To summarize the overall impact that digital data, medical devices and software applications could have on EMS and their influence on how EMS and 911 systems might operate in the year

2020 and beyond, including the potential for impacting downstream cost savings to the health system and influencing new service opportunities for EMS.

- To synthesize available and emerging digital and mobile technologies and software applications marketed to the prehospital and 911 communities. What are the common technologies in use today? How are they used? What are the emerging technologies of which EMS should be aware?
- To present a model for how these technologies might be used by EMS and 911 systems to improve patient care, systems operations, and performance measurement.
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- To consider policy, legal, organizational, and regulatory challenges that must be addressed before the use of new digital data, medical devices and software applications.
- To educate the EMS and 911 communities about what is possible with emerging technologies and software applications.

Methodology

This white paper utilized numerous information sources and expert perspectives in assessing the role of digital technologies for EMS. These review tasks included:

- *Identify and Review Literature and Best Practices for Key Study Areas*. The literature review consisted of academic research on the clinical use and value of mobile devices for EMS and 911 systems and case studies of real-world implementations. Environmental scans included searching business and marketplace literature on current and emerging technology trends and mobile software products and devices for EMS and 911. A listing of reports and articles reviewed is provided in the References section
- *Consult Subject Matter Experts*. We conducted background discussions with 16 industry experts to gain insights about the impact that policy, technology, and EMS operations have on the design, selection, and development of digital technologies for EMS and 911. A listing of subject matter experts consulted for this project is contained in Appendix 1.
- *Develop Review Framework*. Literature relating to technology enabled process improvements, the EMS chain of survivability as well as trends in emergency and community paramedicine was reviewed to develop and extend the concept of the EMS chain of treatment and survivability to an "EMS Continuum of Care" framework.
- *Conduct Analysis of Digital Technology Influences on EMS*. An "EMS Continuum of Care Model" was used as a framework to analyze technology influences on utilization of EMS, including technical, economic and policy.
- *Synthesize Information and Develop Findings*. Based on this review a set of key findings and considerations were developed and are presented below. The preliminary findings and considerations were presented to the National EMS Advisory Council (NEMSAC), and the final report prepared based on their feedback, and well as feedback from the U.S. Department of Transportation liaison and two expert reviewers.

FINDINGS

Results have been organized into an interrelated set of findings summarizing the potential impact of digital technologies on EMS. The findings begin with a synthesis of technology advances in EMS, then introduce the concept of the EMS Continuum of Care, and consider how technologies are affecting various phases in the continuum. From there the focus changes to consider the business, policy and institutional factors associated with current and future technology utilization. Finally, the evolving value proposition for enhanced technology utilization is outlined, with a final consideration of the implications for EMS.

FINDING: Digital technologies have caught up with, and in some cases surpassed, technology descriptions provided in the EMS Agenda for the Future.

A convergence of hardware, software, network, and social and business expectations are creating an environment for innovations to occur across industries. Due to improvements in software methods and available tools, designing and building innovations has become faster and less expensive.[(3)] Social and mobile technologies, big data analytics, and cloud computing are concepts that represent the foundation of major modern innovations,[(4)] and the current and potential impact of these technologies on healthcare transformation have been widely discussed.[(5-8)] Combined, these allow multiple devices and applications to connect people with one another, provide meaningful information, and interact in real time.[(4, 9)] *Mobile and wireless technologies* provide portable, easy to use, and powerful computing capabilities, connecting people with data that were previously not available.[(10-13)] *Cloud computing* allows for more cost effective and accessible software applications over the web (e.g., online banking, email), information services (e.g., weather, maps, traffic), and access to a wide array of data.[(12, 14)] *Social media* both reaches out and pulls in personal information to and from one's peers, customers, and the public.[(15)] *Big Data* promises to allow for analysis of massive amounts of data across a variety of data sources – not just to perform complex retrospective studies, but to gain more real-time intelligence.[(12, 16)] While these technology concepts open up new capabilities for EMS, wisdom and caution are required. These technological concepts are being interpreted broadly, widely accepted, and implemented across industries, yet are still far from perfect and are limited in terms of consistency and security. [(4)]

Nevertheless, today's technologies offer many opportunities. In the introduction to the "EMS Agenda for the Future" (*Agenda),*[(2)] an example was provided to illustrate a 1996 vision of a future EMS care episode (see Appendix 2 for the original scenario). Below, the same example is revisited using 2013 terminologies, while focusing on technology and taking some liberties to expand upon the encounter.

Joe's wife notified 911 using a voice activated Internet Protocol (IP) based Next Generation 911 home monitoring device that allowed the public safety answering point PSAP operator to quickly identify the global positioning system GPS location of the caller, place the location on a digital map, query Joe's chief complaint, pull his recent health history along with his most recent electrocardiogram (ECG) from his primary care physician's electronic health record (EHR) system, and send it forward to the nearest available and appropriate EMS crew for dispatch.

The driver of the dispatched ambulance crew used the automated onboard route guidance system to direct the shortest, fastest, and safest route. Intelligent mapping technologies were also used to assess landscape characteristics of the destination location to predetermine ideal vehicle placement. The *responding paramedic, using mobile smartphone devices and on board tablet computing device, was able to view Joe's (age 60) patient history, his recent ECG, and query additional patient information through the community Health Information Exchange (HIE). Upon arrival, Joe's neighbor showed the paramedic an ECG reading he took on Joe using his own personal smartphone app. However, the paramedic was quickly able to use her own smartphone to determine that the neighbor's app was not medically approved. The paramedic used her own integrated, data enabled portable diagnostic device to assess carbon monoxide levels, obtain a new ECG reading, as well as Joe's vitals. A mobile smartphone app was also used to translate Joe's Russian language to English. All data were accumulated in an integrated, web based patient care record system.*

Analysis of all the data, along with a video conferencing consultation with an EMS physician, suggested a 96% probability of acute myocardial ischemia. Thrombolytics and IV antioxidants were administered, and the nearest cardiac care center was identified and alerted for cardiac catheterization activation. Data accumulated across 911, dispatch, and EMS crew activities were immediately made available to the receiving facility for patient registration and review by the cardiac team.

In follow-up, it was determined that Joe had been noncompliant with his previous medication instructions. Internet links to standardized video training (in Russian) were delivered directly to Joe via text message, email address, social networking page, and smart TV app. Joe's home health care provider was notified when Joe completed watching the videos – which were aimed at increasing understanding and compliance. Clinical follow-up occurred to ensure that Joe understood his health care instructions and to begin minimizing all of his risk factors.

The primary care provider contracted with the Community Paramedics to conduct periodic visits, each of which were tracked using mobile data collection devices linked directly with the primary care provider's electronic health record (EHR) system. Each visit contributed data and diagnostic outputs to Joe's EHR where automated data analytics could provide ongoing monitoring of Joe's key cardiac health indicators. As a result, Joe lived to be 96 years old.

From a technological perspective, such a scenario is entirely possible and more feasible than it was 13 years ago. Technologies today exceed the wireless "PDA" capabilities once imagined. Yet, by and large, from a technological perspective, EMS has not achieved the above scenario across EMS systems in the U.S. A range of challenges have been noted as the cause for slow implementation of advanced technologies in EMS. These are described further in the sections below.

FINDING: The original information systems section of the EMS Agenda for the Future provided 5 goals that, 13 years later, could be enhanced by providing additional specificity and inclusivity of data.

While considering the future of technology, it is also important to review the past. The 1996 *Agenda* set forth five goals for the EMS information system of the future as follows:

(1) adopt uniform data elements and definitions, and incorporate them into information systems;
(2) develop mechanisms for generating and transmitting data that are valid, reliable, and accurate;
(3) develop information systems that are able to describe an entire EMS event;
(4) develop information systems that are integrated with other health care providers, public safety agencies, and community resources; and
(5) provide feedback to those who generate data.

Several reports have noted continuous progress of the information systems goals presented in the *Agenda*, particularly in regards to goals 1 and 2.[17] Implementation of standardized National EMS Information System (NEMSIS) Gold compliant electronic Patient Care Record (ePCR) systems at local and state levels, with regular reporting of NEMSIS data from local to state agencies, and from the State to the National repository represents significant accomplishment.[18] The standard includes methods to exchange data with a variety of other systems, and vendors have built in capabilities to ensure valid, reliable, and accurate data collection and transmission. Some EMS agencies have extended their capabilities to include linking NEMSIS data with a range of public health, hospital, and public safety data systems in order to conduct meaningful local and state level analysis and research. The majority of states (n = 42) are now collecting NEMSIS data, and 39 states reported having the ability through law or regulation to require data collection and submission to the state, while an additional 8 states planned to do so in the near future.[17]

While the progress is significant, work is still required. Data from the 2011 National EMS Assessment showed that only 11 states reported collecting 100% of their States' EMS events, less than 50% of the States that require local EMS agency data collection are currently enforcing the requirement, and data submission frequency also varied significantly across reporting states. Only 11 states require data submission within 24 hours of an EMS event, 13 within 30 days, and 11 within 90 days,[17] demonstrating a gap in the completeness and timeliness of data collection and reporting.

Perhaps an even more significant set of findings relative to the *Agenda* goals is what is <u>not</u> explicitly stated. An important addendum would be to consider *how, when, and where* EMS data are collected, used, and shared, particularly for goals 3, 4, and 5. Several comparative dimensions have been identified for assessing the level at which data are *collected*, *analyzed*, and *shared/integrated* in EMS. These include:

1. Timeliness: Retrospective vs. (Near) Real-time. Several reports released since the *Agenda* was published have highlighted the need to focus on real time transmission of data, particularly across prehospital and hospital environments.[19, 20] Merely collecting data in a National EMS Information System (NEMSIS)[21] Gold level compliant software system to describe an entire event does not ensure that the event is described *when* it is needed for critical operational and clinical decision making (Goal 3). The time at which data are collected, analyzed, and shared matters for rapid and informed decisions to be made. And while not all EMS responses require rapid decisions, timely decisions are nonetheless important for effective resource and patient decision making across prehospital and hospital organizations (Goal 4).
2. End-to-End Completeness: Start vs. finish. Where does an EMS event begin and end? (Goal 3) The answer may depend on what clinical or operational question is being asked. With the rapid growth of home health care, hospital discharge follow-ups, rehabilitation services, Accountable Care Organizations (ACO's), Community Paramedicine, and a wide range of technologies that allow continuous and remote monitoring and health consultations of high risk patients, prevention activities may blend into emergency activities, which may blend into follow-up and prevention activities (Goal 4). Information systems are required to assemble data across a full continuum of EMS care, rather than focus on a narrowly defined episode of care.
3. Degree of Automation: Manual vs. Automated, Human vs. Machine. Automated data collection, analysis, and sharing is key to enabling more real-time decision making and passing essential data to upstream and downstream providers to ensure continuity of care. Opportunities exist to help describe an EMS event as actions take place, but with as little human intervention as possible so as to free up the hands of EMS personnel (Goal 3). A successful example is the use of

automated and connected vehicle technologies to automatically avoid crashes, and to detect and report crashes. A second example is the automated collection and transmission of a digital ECG image. As noted by Dr. Greg Mears, "technology is becoming a more integral member of the EMS team, a member that increasingly performs critical functions in the background."

4. Location: Location is an important factor of analysis. Collecting micro level time and space information is now commonplace in travel, socialization (e.g., taking pictures), and logistics (e.g., tracking goods and services performed) and is done so in order to provide a more micro level view of events across an episode. Visualizing where and when events occurred across the EMS continuum of care can help provide important insight into improving how, when, and where future improvements can be achieved (Goal 4).
5. Scale: Individual Patient vs. single Mass Casualty Incident vs. Public Health Outbreak. Complexity increases as the scale increases. Information systems must take into account the contextual scale of describing a major event (Goal 3), including the full range of involved organizations, data integration points (Goal 4), and the ability to provide a clear picture of events and timely feedback to all pertinent entities that generate and consume data (Goal 5).

Inclusion of these concepts when considering the *Agenda* goals provides a much broader view of what could be achieved with information systems in the future.

FINDING: A common, integrated view of the role of EMS provides a foundation for the wide scale design of technologies that support its mission, goals, and objectives.

A significant challenge for EMS is that EMS systems operate differently from location to location.[(19)] For example, the National EMS Assessment noted 44 different roles and responsibilities carried out to varying degrees across state and territorial agencies that regulate local and regional EMS organizations or operations.[(17)] Since the late 1960's, the development and maturing of EMS systems has taken place at the community level, "with considerable variation in which organizations provide service, as well as the type and level of service provided.[(22)]" Core EMS functions rest upon a wide variety of multi-organizational relationships, management and governance structures, and shared technological systems that create variation in service from location to location.[(23)] EMS involves multiple service delivery models across public, private, and not-for-profit organizations, volunteer and paid professionals, and EMS skills sets integrated across law enforcement, fire, medical institutions, rescue services, humanitarian aid organizations, educational institutions and a variety of other entities. As noted in the 2011 "NG911: What's Next" report, "…emergency medical services may be viewed, both internally and externally, as a service that is provided, rather than a distinct profession."[(22)]

Because a major role of digital technologies is to support and integrate operations, work flows, and organizational responsibilities, it follows that the technologies that are used to enable EMS systems differ significantly from one another as well. It is thus challenging to present a specific set of technology directions for any one EMS organization when the business, service, and operational models vary to such a degree across each of them. Therefore, in order to address the technology questions of this paper, it is essential to understand *what* EMS *does* from a high level, architectural standpoint.

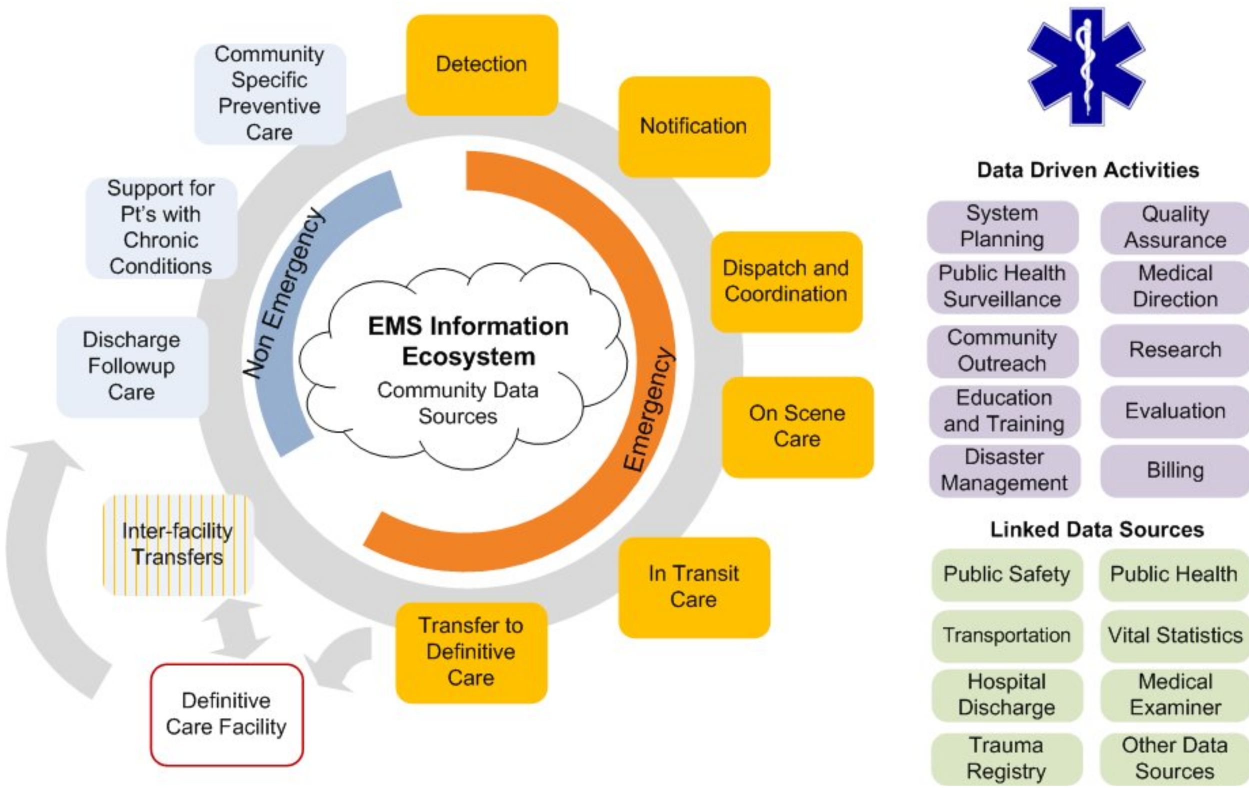
Historically, EMS has focused on *providing emergency treatment* for persons suffering from serious injuries or acute medical problems in community settings, while transporting such persons to a hospital emergency department (ED), and when needed, in the ED until care is taken over by hospital staff [(19)]. EMS personnel also have been utilized to transport ill or injured persons between hospitals, and more recently to assist with hospital discharge follow-ups, care of patients in the community with chronic conditions (e.g., diabetes, asthma, congestive heart failure), and assist with primary and home health care activities. [24]

To help in this assessment, a high level review framework was developed to determine how and where digital technologies might impact operations and clinical care. The framework assimilates a wide range of traditional and emerging activities into a core set of activities. It was developed drawing from concepts in technology enabled process improvement and knowledge discovery,[25] a process-oriented time-critical information services (TCIS) evaluation framework,[26] the EMS Star of Life concept (i.e., detection, reporting, response, on scene care, care in transit, and transfer to definitive care), National Highway Traffic Safety Administration (NHTSA) publication materials describing the role of EMS (see for example [27]), the EMS Chain of Survival concept (originally developed for cardiac, but expanded over time) and recent reports on the role of EMS in non-emergency settings. [24, 28]

Figure 1 illustrates an integrated view of the EMS Continuum of Care based on the above review. The actions surrounding the circle represent key patient-centered activities carried out by EMS in the process of responding to and caring for patients, taking into consideration the traditional emergency model as well as non-emergency practices that have become more prevalent in Mobile Integrated Health and Community Paramedicine systems. At the center of the circle is an information ecosystem that securely collects, integrates, analyzes, and shares data when and how it is needed across the continuum. On the outside of the circle, the model also includes example high level activities that EMS is often responsible for, and for which data are essential to carry out effectively. Data that are generated during patient-centered care activities are used to feed and *enable* effective system planning, quality improvement, medical direction, public health surveillance, and all other major EMS activities. Information systems and the data produced thereby are critical to each of the EMS attributes as described in the *EMS Agenda* including: Integration of health services, EMS research, legislation and regulation, system finance, human resources, medical direction, education systems, public education, prevention, public access, communication systems, clinical care, evaluation, and information systems themselves.

Data sources external to EMS are also essential for conducting data driven activities and for conducting patient-centered activities, and thus should be closely linked. While the EMS Continuum of Care model is not meant to be comprehensive and inclusive of all possible EMS actions and responsibilities, it provides a common view for discussing technology opportunities and challenges.

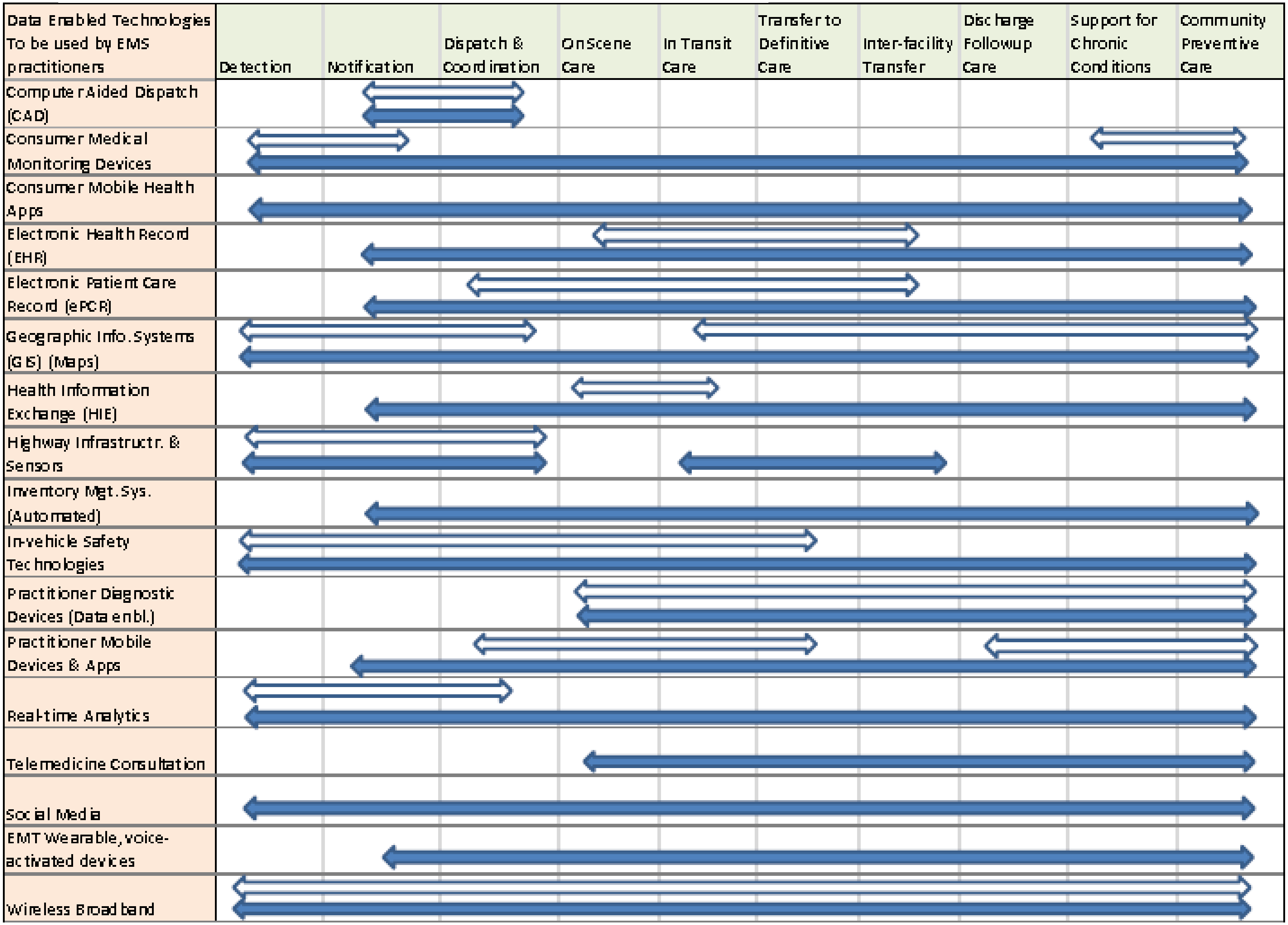
Figure 1. The EMS Continuum of Care



FINDING: Technology developments are occurring across the EMS Continuum of Care, although important gaps remain.

There are a plethora of technologies being developed, tested, and deployed across the EMS Continuum of Care. Some of these are summarized in Appendix 3, as well as in Figure 2. The following is a general summary of technologies that are: 1) commonly implemented (white with blue outline arrows) and 2) poised to be implemented across the continuum in the future (solid blue arrows). It is important to note that the white with blue outline arrows are not meant to describe *what* is available by the vendor community today, but rather what is commonly implemented and used based on the analysis conducted. Certainly, some technologies have been pilot tested (e.g., a variety of Consumer Mobile Health Apps), and others are used regularly in a limited number of locations (e.g., HIE, EHR). This list is also not meant to be comprehensive in terms of the types of possible technologies. A future activity may be to inventory and describe the wide range of technologies available in the marketplace along with those that are emerging, to illustrate current gaps and future opportunities. A future use of this chart could be to not only describe where a certain technology exists across the continuum, but the level of advanced functionalities that are being utilized. For example, not all consumer medical monitoring devices are alike in terms of their purpose and capability. Thus, a more beneficial use of Figure 2 would be to describe the specific features that can be utilized across the Continuum of Care and compare the current technology feature with those that may be under future consideration.

Figure 2. Technologies commonly implemented and used in EMS (White with Blue outline), and future implementation (Solid Blue)



Below, each of the Continuum of Care activities is summarized, providing a general, non-comprehensive description of how some of the aforementioned technologies *could* be used in the future across the model.

Detection. Today, detection of an emergency medical condition is largely a human decision process. An individual typically detects and then calls 911. While human detection will likely continue into the future, a wide range of medically approved, as well as personal monitoring devices will also be used to determine when a health emergency is occurring. These devices may be implanted (e.g., pacemaker), worn externally, be driven (i.e., vehicles), or reside on external devices (e.g., smartphone devices).[29-31] Detection devices could measure, for example, heart indicators (e.g., ECG), blood-glucose levels (e.g., using a modified mobile smartphone device), and the likelihood of injury (e.g., Advanced Automatic Crash Notification (AACN)). These “data enabled” medical and consumer devices are expected to become more widespread and less expensive as they become integrated into homes, vehicles, modern Smartphones, mobile tablets, wearable computing devices, and a wide range of other mobile devices.[32] Challenges to computer assisted detection include the need for control, accuracy, and standardization of these devices, the extent to which Food and Drug Administration (FDA) approval is required for their use,[33] as well as how and when they will interface with Next Generation 911 systems.

Notification. The U.S. emergency system was founded with the concept of a universally accessible emergency number (i.e., 911) for reporting a public safety or health emergency to a PSAP. With Internet Protocol (IP) based Next Generation 911, mapping technologies (i.e., GIS), advanced automatic crash notification (AACN), and a range of new devices and systems coming to market, 911 notifications will become even more accessible to a wider array of people and technological systems. The future holds the promise to broadly extend the precedent that was set by AACN. As high quality data proliferates from new detection and notification devices, a much more robust layer of intelligence will report the likelihood and degree of severe injury, or likelihood and degree of a range of other medical conditions to the appropriate PSAP (i.e., cardiac, stroke, pneumonia, infections). As these devices become more sophisticated, they will aid in directing patients to the most appropriate communications medium for their condition – whether emergency or non-emergency related. Such data will, in some cases, continue to create more automated dispatch processes; and in other cases, data will enable dispatchers to make more informed decisions with a cleaned, filtered, and visual set of information. PSAPs will continue to take advantage of virtualization technologies and be able to dynamically expand the number of operators by making use of available call takers in other regions. From the public eye, social media will continue to create a sense of transparency into the EMS services that are provided and EMS will have found new ways to demonstrate its value using social media. Challenges to reach the future include funding constraints that lead to slow implementation of Next Generation 911 and continued pressure and/or resistance to consolidate PSAP resources across regions, slow adoption of technology standards that enable interoperability between PSAP technologies (e.g., Computer Aided Dispatch), and slow roll-out of open systems by vendors. Other potential challenges include a proliferation of IP devices and information that stand to stress the 911 system while the future is being developed.

Dispatch and Coordination. PSAPs receive and handle calls, locate a caller, determine the issue, dispatch and coordinate resources, and may provide medical pre-arrival instructions to a caller. These tasks are accomplished using Computer Aided Dispatch (CAD), Geographic Information Systems (GIS), two-way radios and landline phones, and emergency medical dispatch (EMD) software (respectively), to name a few. PSAPs may also receive and report weather, traffic, public safety, public health, resource availability, and a range of other information via voice, video, or data. EMS is dispatched via radio, pager, onboard Mobile Data Terminal (MDT), or text message with location, chief complaint, and basic demographical data. Future dispatch will include automated and intelligent assistance for dispatchers and EMS personnel using the wide array of information available to them. Rich data will allow for near real-time risk assessments for both patients and EMS crews. New sources of information, as well as dispatch resources, will also become available for pre-arrival preparation. For example, preexisting health information from the community health information exchange (HIE), hospital bed status, advance directives, emergency medical dispatch (EMD) codes, updated EMS policies and procedures, and knowledge about other available resources (e.g., bed status, air transport) will be more fully assimilated to provide a robust set of potential and probable courses of action *prior to arrival*. Available telemedicine resources will also be coordinated into a response. For example, available telepsychiatry or teletrauma services in the region will be linked-in to provide on-scene medical consultations. Mobile apps will also provide a wide range of just-in-time video training for paramedics who are new or dealing with low frequency high criticality conditions. Challenges for the future include developing the organizational relationships and funding structures to share resources and exchange information, and the ability to assimilate a wide range of information for quick and effective decision making using an underlying backbone of telecommunications equipment and financing structures that are complex and quickly becoming outdated.(34) Algorithms needed for automated dispatch decision making for many health conditions are only in their infancy, with the exception of technologies such as AACN. Finally, lack of integration of EMS and public safety with the healthcare system at large presents significant barriers to this future.

The coordination of emergency response organizations extends beyond the command and control responsibilities of PSAPs. It also includes the need for on scene personnel to work well together. In the future, mobile devices, interactive and interoperable databases, and secure wireless broadband networks will enable a “snapshot view” needed by field responders, including which resources are on scene and which are available if/when needed. One expert refers to this vision as a “Common Operating Picture” that is needed by all response organizations.(35) Challenges to meeting these capabilities, including the wide range of data and technology standards required, are being addressed through Next Generation 911 efforts and through FirstNet, a public safety broadband network to be implemented over the next several years.(36) Other major challenges include defining the information that should be visualized, how and when it is visualized, and which algorithms and policies should govern automated vs. manual decisions.

On Scene Care. When EMS personnel arrive on scene, patient conditions are assessed, care provided, and information collected from across a range of family members, bystanders, and any other available source of information (e.g., prescription medication bottles). On scene care in the future stands to change significantly due to major technology advancements. Mobile devices continually become more powerful, more affordable, and easier to use. For EMS personnel, wearable, hands free, and voice activated devices will be used to collect a range of voice, video, and images. Geographic Positioning Systems (GPS) will enable more accurate time and location tracking, and RFID tags will enable automated tracking of inventory used per incident. Patient and incident Information will be aggregated from patient owned monitoring devices and bystander devices into an information “tub” to share with other downstream providers and systems (e.g., ePCR, EHR) using NEMSIS Gold Compliant systems and applicable EHR/HIE standards. Preexisting patient information will become more available and accessible through community or statewide Health Information Exchanges (HIE). Diagnostic devices will also become more miniaturized, affordable, and data enabled. For example, video assisted laryngoscopy, point of care ultrasound, pulse oximetry, blood oxygenation (SpO2), pulse rate, and perfusion devices could all provide images, data, and video as appropriate to be captured and presented to downstream providers. These device technologies, along with other patient and environmental information, will also enable more real-time clinical decisions – such as EMS safety precautions, likelihood of patient condition deterioration, and recommended procedures, mode of transportation, and destination facility. EMS will also know what additional resources are available if needed (helicopter, facilities). In addition, an array of devices will monitor risk factors for EMS personnel in the field to reduce the probability of injury.

Many challenges exist to achieving such a future. Across the U.S. today, data collection is often not conducted *on scene* using an electronic device. Information is rarely queried from other sources (e.g., EHR, HIE),[17] and digital data collected on scene is not consistently transmitted to a health care provider while delivering prehospital patient care or even at patient handoff to an emergency department.[37-39] Communications between transport and a receiving facility are primarily radio based – leaving a great deal of potential for information handoff gaps and health care errors that follow.[40] While FirstNet is slated to significantly advance EMS connectivity to wireless broadband in the future, today video and digital image transmission by local EMS agencies to medical control is uncommon.[17] Electronic data collection systems (e.g., prehospital electronic patient care records (ePCRs)) are commonly used for post incident documentation rather than for real-time data capture and clinical decision making across the Continuum of Care. Though accessible for military use, wearable, voice activated technologies are not yet affordable or widely available in the commercial marketplace. Vendor equipment monitors, and diagnostic devices are in further need of standards for data/technical interoperability, including openness to access the output data from these devices for use in a variety of other applications. Most significantly, using information technologies on scene is a cost that is not reimbursable. As a result, it is typically the very forward thinking EMS agency administrators or EMS medical directors that find a way to incorporate these devices and technologies to improve the standard of patient care and accountability, while ensuring the financial viability of the EMS service.

In Transit Care. Care provided to a patient in transit is essential, as is the safety of the patient, EMS personnel, and traveling public during the transportation of the patient. In this regard, technology in the future will both improve transportation safety and assist in the care of a patient. In terms of transportation, vehicle to vehicle communication technology will be customized for EMS vehicles, due to EMS using the transportation system differently than other vehicles (e.g., driving on the wrong side of the road and shoulder of the road).[41] Driver navigation systems will also be customized for these specialized vehicles to provide the fastest and safest route as per the level and degree of emergency (lights and sirens vs. non-emergency). The back of the rig will have been designed to integrate technology. For example, device monitors and computer screens will be positioned effectively, electrical power adequate, and patient information easily accessed and recorded. Care provided in the patient care compartment, changes to health status, any inventory used, and vehicle mechanical status will be updated into the information "tub" for downstream providers and support staff to access. Much of the data collection will be automated and voice activated. Challenges to achieving this future include immature vehicle to vehicle technologies, a lack of updated EMS vehicle design guidelines to incorporate technology and safety, and the array of challenges described above in the "On Scene Care" section.

Transfer to Definitive Care. Information systems in the future will enable seamless information handoffs from the prehospital care setting to hospital/facility setting. A receiving hospital will be able to access all relevant patient information as soon as the destination decision has been made on a pre-arrival basis, regardless of whether an ePCR has been completed. Furthermore, all information will be available through a single user interface within the appropriate facility location (emergency department, operating room, radiology, etc.). Automated notifications will be made to the facility computing devices of choice to prompt early activation of appropriate resources (e.g., trauma, STEMI[1], stroke). Ambulance unit information, estimated time of arrival, and all key and relevant data will be provided via the interface with near real-time updates. Digital voice or video reports by EMS personnel are available for each and every downstream provider. Integration with the facility EHR is automated, and depending on the patient condition and facility, registration is also automated. Prehospital data are available for making automated resource decisions in the hospital based on pre-determined procedures and algorithms.

Challenges to reaching this future are immense. A national survey showed that a patient care record is available for ED physicians for less than 50% of EMS patients.[(37)] There exist few legislative or financial incentives to integrate data systems across prehospital and hospital environments. For example, of the 48 States providing information for the National EMS Assessment, just 23 (48%) have a requirement to leave a formal copy of the EMS patient care report with the patient's receiving healthcare provider at the time of transfer.[(17)] On the health care side of the equation, medical facilities and practices have been incentivized to implement EHRs, yet EMS has not been included in the billions of health IT grant funding dollars Congress has allocated through the U.S. Department of Health and Human Services (HHS).[2] Thus, integrating EMS provider information into the emergency department chart, or EHR, is not included as a legislative or financially incentivized requirement. As a result, EMS data systems remain largely siloed from health data systems. Many ePCR vendors have developed interfaces for integration, but implementations for near real-time, point of care information sharing are far and few between. Often where an ECG, ePCR, or point of care ultrasound images can be captured and transmitted, each is sent to a separate interface in the ED – and often not associated with an ePCR or EHR. Disparate data causes confusion and can be easily missed, potentially leading to medical errors.[(42-45)]

Inter-facility Transfers. As with emergency transports, interfacility transfers are conducted by hospital based, publicly operated, or privately operated transport agencies. Similar to the "In Transit Care" and "Transfer to Definitive Care" activities described above, future information systems will enable all the information needed for an inter-facility transfer to ensure patient and EMS crew safety, and seamless transfer of patient information from one care setting to the next. This will include ongoing system and unit status information as described above. Data integration is key to obtaining patient information from one facility EHR, creating an interfacility ePCR, and handing off pertinent data to the receiving facility. Thus the challenges outlined above are just as relevant. Anticipated and actual demand for services will also be available to crews and system managers for more effective resource allocation and planning.

Discharge Follow-up Care, Support for Patients with Chronic Conditions, Community Specific Preventive Care. There is a growing interest in Community Paramedicine (CP) in the U.S. Characteristics of CP include transporting patients to appropriate emergency care services, providing follow-up visits to recently discharged patients to ensure patient understanding and adherence to discharge instructions, and to collaborate with community primary care providers and other health providers to assist in providing care to people with chronic conditions.[(24, 28, 46)] To accomplish this, the technology of the future will enable information exchange with healthcare systems to access, view, and track patient visits using mobile devices that transmit and store data on secure cloud servers. Patient information is accessible through community health information exchanges and visits are requested by health care providers. Video educational material in a wide range of languages will be used to explain medical conditions, medications, and care procedures in versions for EMS personnel and for patients and their family members. Visit scheduling systems will be multi-dimensional, sending EMS personnel to conduct

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[1] ST segment elevation myocardial infarction (STEMI). Accessed on Sept. 29, 2013 at: http://my.clevelandclinic.org/heart/disorders/cad/mi_types.aspx

[2] See: http://www.healthit.gov/policy-researchers-implementers/hitech-act-0

prioritized visits in their geographical location while not on an active emergency run. Challenges to achieving this vision include establishing the business, organizational, and policy environment for CP to occur, the financial relationships to fund CP activities, the need for technical interfaces to hospital EHR systems to allow for visit and patient care tracking, and the underlying logistical systems to track EMS resources to enable intelligent resource utilization.

Data Analysis. Data are required to assess the performance of every major EMS function, from billing to quality assurance/improvement, to educational needs. The methods to measure performance in a standardized way has developed significantly since 2002, and efforts across EMS leadership continue to progress.(47) In many locations, EMS data are used for public health surveillance and this has proved beneficial. In a recent national survey, 21/49 States (43%) reported including EMS data in their public health surveillance systems.(17) Today, databases, data warehouses, and business intelligence systems are becoming more commonplace in EMS. Many ePCR systems provide built-in data analysis and reporting capabilities. Vendors' solutions are also provided for conducting public health surveillance, monitoring available public safety and health resources, and providing health risk indicators. The systems in the future will enable advanced analysis and reporting capabilities not only for retrospective studies and post incident quality assurance, but also to gain more automated and real-time intelligence to facilitate performance improvement. These systems will become smarter yet far more complex in their interactions with other data systems to more quickly and accurately identify and even predict high risk patients, public health concerns, and other important attributes. Geographic/map based analysis will be commonplace. Analytical systems will be able to process increased volumes of data from a wider range of EMS Continuum of Care activities, and massive amounts of real time data from other sources including public social media interactions, news feeds, environmental systems, transportation systems, education systems, genomics, and others. Unfortunately, most EMS systems are still not able to conduct analyses across the full spectrum of care. Future capabilities will include analysis of patient outcomes from hospital EHR and/or registry systems for time sensitive systems of care (Trauma/Stroke/STEMI). A significant barrier to achieving the future is a lack of technical interfaces with hospital data systems. Lack of interfaces with public safety, transportation, and other public health databases also poses challenges. These are due to political, policy, and financial constraints, fear from hospitals that sharing data will jeopardize their core business, and fear of patient privacy and security breaches. Other major challenges include a lack of professionals in the EMS industry with the required data and analytical skills sets. Furthermore, hiring such individuals is costly as such skills are in high demand in the marketplace.

FINDING: Business and policy models limit the role of EMS and its use of technologies across the EMS prehospital elements of the EMS Continuum of Care.

Challenges affecting the adoption of technology in EMS have been broadly documented by the authors and others.(23, 39, 48) These include business, organizational, policy, cultural, institutional, and financial constraints. The key question in the year 2013 is not *what* technologies exist, or *when* will the technology become advanced enough to enable benefits. Rather, the question is *how* to take advantage of the available opportunities and potential benefits? How can advanced technologies be integrated into clinical care on a broad scale? How can EMS organize itself to take advantage of the benefits? And, how can it be financed?

Funding

EMS systems are an essential part of the U.S. health care system. They operates at the intersection of health care, public health, and public safety.[19] While the intersection has served to meld these public service domains together, it also poses funding challenges. As noted by the 2006 Institute of Medicine report "EMS at the Crossroads," local EMS systems are not well integrated with any of these groups and therefore receive inadequate support from each of them.[19]

The "NG911: What's Next"[22] report explains:

> *While the other responder groups…fire departments, law enforcement agencies and transportation operations — typically receive funding from public sources, not all EMS systems do. In fact, many EMS systems operate either with limited public funding or in some cases without any. With limited exceptions, only transporting ambulance services can bill for services, and only when they actually transport a patient (as opposed to, for example, treating and releasing, or assisting a patient who subsequently refuses transport). Agencies that provide emergency medical first response but do not transport are currently not eligible for reimbursement.*

For organizations that receive the majority of their funding from Medicare, Medicaid, and private insurance reimbursements, there is little or no financial incentive to treat emergency patients at the scene of their illness or injury or to transport them to a provider other than an emergency department. As suggested above, significant funding and incentive challenges exist for prehospital emergency transport services. Medicare reimbursements are paid on a base rate plus mileage for transporting a patient, while other healthcare providers are paid for visits and "procedures" conducted. One recent report described the total distribution of reimbursement funding for EMS to be as follows:[49] Medicare: 44%, Medicaid: 14%, Private Payer: 14%, Commercial Insurance: 21%, Other: 7%.

As these figures suggest, Medicare is a major driver of the EMS business model for the "on-scene care" through "transfer to definitive care" phases of the EMS Continuum of Care (Figure 1). The average Medicare rate for transport is $429 per transport, resulting in an estimated $5.2 billion in annual payments by Medicare. Furthermore, for EMS to collect $464 in reimbursement, the EMS agency triggers an emergency department visit at an average societal expense of $969. New models of delivery to reduce EMS transport and ED visits have been proposed in terms of the potential for downstream cost savings. One such model noted that 15.7% of all Medicare EMS patients are treatable outside the emergency department, and that implementation of triage and treatment protocols could save Medicare between $283,464,058 and $559,871,117 [50]. While the debate on this topic will likely continue, the focus here is on the implications of reimbursement alternatives in relation to the demand for EMS Continuum of Care technologies.

First, the general health care cost challenges in the U.S. pose significant opportunities for EMS systems to be part of the solution and help reduce the incidence of costly care for unscheduled patients. New initiatives may allow EMS systems to demonstrate innovative strategies to reduce total cost of care and increase health outcomes. The role of technology will be central to such initiatives, including remote health monitoring of medically needy patients, facilitating telemedicine consultations (e.g., teletriage and teletrauma), and identifying high risk patients in the community, along with assessing the probability of a patient encounter. Such actions would require greater availability of monitoring a wider range of health care resources and facilities, performing real-time clinical analytics on a patient to determine appropriate on-scene care or facility for transport, and tracking patient encounters across the

EMS Continuum of Care in order to assess cost savings in relation to quality of care. EMS should play a central role in assuring that the underlying telecommunications infrastructure, data infrastructure, analytical tools, and level of integration is designed effectively to achieve desired results.

The existing funding model has limited the capacity for EMS to utilize new digital technologies to improve care. The most immediate implication is that the EMS providers have very little "slack-resources" to invest in technology. EMS organizations are left to find creative ways to fund technology initiatives, for example, through grant funding and local and state public financing. Unlike the Health Information Technology for Economic and Clinical Health (HITECH) act that incentivizes health systems to adopt Health Information Technology,[51] no such incentives exist with regards to the response, on-scene care, in-transit care, and transfer to definitive care elements of EMS. Thus, while the technology-space may be abuzz with various new applications and innovations, there is tempered demand due to lack of business and financial incentives within the EMS industry.

FINDING: Strengthening the EMS Continuum of Care with information technologies could lead to operational and health benefits.

Evidence of the positive impacts of technologies on EMS operations and clinical care is varied, diverse, and continuously evolving with technological changes. For this high level review, experts as well as the literature review pointed to a number of potential and expected generalized benefits that could be realized. These include better situational awareness, more informed decision making, more efficient data collection, more streamlined operational management, and potential health care related cost savings. Key points are summarized below:

Continuity of Care.[40, 42, 52] Availability of information when and how it is needed at each phase of the care continuum improves information handoffs from one care provider to the next and thus improves patient care handoffs, reducing the likelihood of medical errors and increasing the potential for a higher level of care.

Improved Resource Utilization.[22] Data availability across the continuum allows for increased intelligence about EMS resources. Effective use of data also enables increased intelligence about the specific needs of each patient. Matching appropriate and available resources with patient needs will create system-wide efficiencies.

Improved Public Perceptions. As EMS is able to demonstrate its value with the data it collects, and effectively communicate that value to the public, the public may gain greater appreciation for its existence. Public demand for service transparency across industries through the use of web sites and social media continues to increase. Likewise, EMS will be pressured to continuously adapt to meet public demand. As EMS is able to do so, public perceptions may also improve with met expectations. As demonstrated in other industries, such as in electronic marketplaces and electronic government systems, improved public trust, perceptions of quality service, and enhanced accountability can result when services, service providers, and associated performance is widely known. However, transparency of information can also be detrimental where a system fails to meet public expectations, or when citizen privacy is breached.[53, 54]

Intelligent Decision-Making.[22, 35] Many decisions are supported by data and technologies. Where it is possible to automate decision making and action, time savings will occur, human error will decrease, and patient needs will be addressed. Advanced automatic crash notification (AACN) provides an illustrative example where an onboard vehicle system automatically detects and reports a crash and sends detailed crash data that identifies the probability and severity of injury.

Improved Response Times.[22] The public expectation is for a fast emergency response. Emergency response times may improve for those patients that are truly in need of emergency services. This may result from devices that detect medical issues faster and automated protocols and processes that allow for skipping over slower, manual processes. However, average response times may not improve as a whole in the future as patients not requiring emergency care are transported to more appropriate care facilities – a decision that will likewise be assisted with technology.

Improved Patient Care.[22] Timely and appropriate care will likely lead to better patient outcomes. However, it is the responsibility of the EMS community to demonstrate that it is achieving this core metric. Data systems across the continuum will enable such assessments.

Improved Patient and Practitioner Safety.[22] Patients may be safer due to better operational and design decisions being made on their behalf. Both practitioners and patients will be safer due to more intelligent vehicle safety systems for navigation, driver assistance, crash avoidance, and vehicle to vehicle communications customized specifically for EMS vehicles.

Improved Research.[2, 20, 55] A robust information continuum may create data and associated linkages with other data systems that allow for meaningful research to be conducted, the findings of which would be incorporated back into the improvement of the EMS system.

Improved Situational Awareness.[35] EMS requires good knowledge of available resources and relevant events in the community that will impact decisions, for example, vehicle inventory, operating condition of vehicle, helicopter availability, volunteer service availability, hospital ED availability, large events taking place in the community, population centers, weather conditions (and forecast), and potential public health outbreaks. Today, a comprehensive view, including dynamic predictions, is not available in a snapshot. For example, while the EMS for Children (EMSC) Program's quality indicator is that 90% of the EMS transport vehicles in each State should carry 100% of the required EMS equipment, national indicators are that 22.5% and 34% of BLS and ALS Transport Vehicles respectively carry 100% of the equipment.[17] EMS personnel typically cannot efficiently access an updated view of what inventory is available through an equipment and inventory tracking system, and thus are not able to quickly assess standards compliance.

Common Operating Picture.[35] As introduced earlier, every applicable responding agency should have access to all incident and patient information available to them as authorized and needed, providing a view of the data that suits each agency's particular needs.[35] These comprehensive and integrated views hold the promise to enable process and decision making improvements across the Continuum of Care. FirstNet represents a major opportunity for EMS to be involved at the outset of building the enabling public safety broadband network to create the underlying support structure across the U.S. Such a network offers significant advancements for secure interagency voice, video, and data communications. The development of public safety and EMS "App" marketplaces, digital network and directory services, and interfaces for connecting devices and applications will provide the backbone for a "Common Operating Picture" to occur across agencies.

Ability to Measure. With a plethora of high quality granular data accumulated across the Continuum of Care, it will become much more feasible to measure compliance with protocols, rules, credentials, certification, policies, and performance. Operational and clinical service quality can be more readily assessed and individuals and organizations can be monitored based on predefined metrics (response times, adherence to medical protocols, etc.). For example, use of health information technologies has been shown to enable measurement and improvement of patient and practitioner safety, increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medication errors.[40, 56, 57] Certainly, the ability to measure is a long sought after benefit of data and information systems.

Ability to Predict. It is feasible that with advanced analytics, predictions could be made on where the next call will be, when a public health outbreak might occur, and which resources will be available in the near future. It will take many years of collecting high quality data, and developing the algorithms needed to improve predictions, in order to reach a high enough level of confidence to be useful. Other industries have gained significant value from predicting consumer purchases, travel behaviors, crime, employment paths, and population health.[58, 59] EMS, and healthcare more generally, stand to gain if such predictions eventually translate to lowering costs and improving service quality.

As noted above, these potential operational and health benefits are forwarded by experts in the field. There is a continuing need to ascertain the validity and magnitude of these benefits through systematic EMS research on new technologies. A series of comprehensive reviews on technology impacts across the EMS Continuum of Care could provide a valuable extension to this work.

FINDING: EMS has a strong relationship with the transportation sector, both in terms of addressing motor vehicle crashes and as a user of the transportation system.

Motor Vehicle Crashes (MVC) represent a significant share of EMS response. According to the CDC (2009), more than 2.3 million adult drivers and passengers were treated in emergency departments as the result of being injured in motor vehicle crashes. The economic impact is also notable: one study that looked at 2005 MVC's estimated that just for national cohort, the lifetime costs of crash-related deaths and injuries among drivers and passengers is approximately $100 billion.[60]

Motor Vehicles Crashes and the EMS Continuum of Care

Recent trends and future developments relative to MVC can and should be viewed from the EMS Continuum of Care Perspective. While the overall decline in MVC fatalities from a high of 54,589 in 1973 to the 34,080 in 2012 has been widely and appropriately praised, less understood is the exact role of vehicle design and technology improvements on this change. A recent (2012) NHSTA study found that over the last decade, a sizable number of MVC have been prevented due to vehicle design and technology improvements:

> *The nationwide impact of these advancements is substantial. We estimate that improvements made after the model year 2000 fleet prevented the crashes of 700,000 vehicles; prevented or mitigated the injuries of 1 million occupants; and saved 2,000 lives in the 2008 calendar year alone. Of the 9 million passenger vehicles that were in crashes, the crashes of an estimated 200,000 of them were preventable by improvements to the model year 2008 fleet, and the injuries of 300,000 of their 12 million occupants would have been prevented or mitigated, including saving 600 lives.*[61]

These significant gains in auto safety through crash prevention are now possible because complex electronics and computer assisted mechanisms have become more feasible and robust. To illustrate, one of the most significant advances in crash prevention, which has been on the market since 1995, is Electronic Stability Control (ESC). A comprehensive evaluation by Ferguson (2007) confirmed the impact:

> *The overwhelming majority of studies find that ESC is highly effective in reducing single-vehicle crashes in cars and SUVs. Fatal single-vehicle crashes involving cars are reduced by about 30–50% and SUVs by 50–70%. Fatal rollover crashes are estimated to be about 70–90% lower with ESC regardless of vehicle type*.(62)

Advanced Automatic Collision Notification (AACN) provides an important example for minimizing injuries. By enabling responders to more quickly identify, diagnose, and treat injuries, AACN data helps to reduce death and injuries among vehicle crash victims. By using a collection of sensors, vehicle telemetry systems like AACN send crash data to a trained telematics call center agent when a vehicle is involved in a crash. Depending on the type of system, the data may include information about crash severity, the direction of impact, air bag deployment, multiple impacts, and rollovers (if equipped with appropriate sensors). Agents can relay this information to emergency dispatchers, helping them to quickly determine the appropriate combination of emergency personnel, equipment, and medical facilities. More importantly, if fed into an urgency algorithm, calculation of probability of severe injury can be automatically performed and relayed to responding EMS personnel. Over the next year, NHSTA will make a strategic determination on AACN, such as whether it may be required on new vehicles.(63)

In terms of response and prehospital treatment, there has been significant interest in improving the timeliness and efficacy of a response, as well as the quality of prehospital treatment. This is particularly true in rural areas, where the majority of severe traffic crashes and fatalities occur, and where the response times (due to geography) tend to be longer.(64) The NG911 initiative provides a template for moving toward an IP based system that will allow for improved emergency call routing and responses. The defining characteristic is elapsed time from incident to definitive care. The role of mobile technologies in expediting time to critical care has received close attention. For example, EMS can provide advanced communication with the ED with regard to key health condition through partial ePCR information transmitted to the ED, as well as ECG data and other vital information. Tests have also been conducted on advance transmission of multi-media (voice, video, data) and its use within the ED for patient registration and treatment.(65)

The limitation of advanced technology use has been the availability of a broadband (mobile) backbone. In part this is a legacy issue, with the majority of EMS providers utilizing radio-based communications with the ED. While advances in commercial mobile broadband represents a major new platform for EMS prehospital communication, concern about commercial broadband availability (such as in rural areas) as well as cost represents a barrier for rapid movement to this new platform. As noted elsewhere, the recently authorized FirstNet system represents a major new development for public safety and EMS broadband. In terms of its impact for motor vehicle crash response, the system would in principal provide EMS responders with greater capacity to transmit live video, images, and extensive data to the ED.

As these advances will take several years to become fully deployed, for many (especially rural) regions Helicopter EMS (HEMS) will continue to represent a major option for dealing with severe motor vehicle injuries. Thus, HEMS is an important mechanism for getting medical crews to the patient that brings important expertise to both trauma scenes and small community hospitals. For example, using data from Oklahoma, a recent study (2011) found support for getting patients directly from trauma scenes to trauma centers utilizing HEMS. The key finding of this study was that HEMS use was associated with a 33% mortality reduction among major trauma patients.[66]

Although the major debates about HEMS center around cost-effectiveness (including overuse) and safety, there are also a number of technological issues to be addressed including enhanced Geo-location, Navigation Assistance (including during inclement weather and at night), and better inflight data communication with the ED.

Intelligent Transportation Systems (ITS) and EMS

EMS occurs on the nation's highways, byways, and airways. The manner in which it uses roadways, its unique vehicle configurations and operations, and vulnerable human cargo indicate its importance as a transportation form. An estimated 28 million EMS patient transports are conducted each year.[17, 19] EMS performs a life critical function for many of these transported patients, including the aforementioned 2.3 million MVC transports. The ongoing development of intelligent transportation systems (ITS)[3] and other technologies for surface and air transportation provides an important opportunity for EMS to participate and address EMS safety and operational issues.

The safety of EMS vehicle transports on the road merits ongoing attention. Between 1992-2011 (20 years), there were an estimated annual average of 4,500 MVCs involving an ambulance. Of these crashes, there were an estimated 1,500 that involved injuries and these resulted in 2,900 injured persons (includes occupants and non-occupants of all vehicles involved). In addition, there were an annual estimated average of 29 fatal crashes resulting in 33 deaths.[67, 68] While these crashes, injuries, and fatalities are very small relative to the total number of MVCs in the U.S., they remain an important concern given the total number of EMT professionals (approximately 900,000).[69] In 2011, the National Institute for Occupational Safety and Health assessed EMS transport safety from an occupational safety perspective. Their research examined 99,400 fatal and nonfatal EMT injuries and 65 fatal EMT injuries from the period 2003–2007.[70] Looking across all EMT fatalities, this study indicated that most (76%) were transportation related, with automobile incidents accounting for 45% and aircraft crashes 31% of deaths. The fatality rate (6.3 per 100,000 Full-time Equivalents) was 1.4 times the rate for all workers during this period, and the EMT fatality rate was found to be slightly higher than firefighters, who had a rate of 6.1 per 100,000 Full-time Equivalents. Other related studies have produced similar results demonstrating high injury and fatality rates for EMTs compared with other professions.[69, 71, 72]

Significant efforts have been placed on improving EMS safety, including reducing transport injuries and fatalities through the application of technologies. For example, one area of consideration has been to enhance ITS and other technologies surrounding EMS transport, particularly through signalized intersections, which is a frequent locale of EMS vehicle crashes.[73, 74] Such technological approaches range from system solutions, such as Emergency Vehicle Priority (EVP) techniques[4][75], to in-vehicle systems that provide driver guidance, alerts and assistance.[76] Additional considerations have focused on enhancing the crashworthiness of EMS vehicles.[76]

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[3] Intelligent Transportation Systems have been defined as: "the application of advanced sensor, computer, electronics, and communication technologies and management strategies—in an integrated manner—to improve the safety and efficiency of the surface transportation system." See: http://www.ops.fhwa.dot.gov/publications/regitsarchguide/1intro.htm. See also: http://www.its.dot.gov/faqs.htm

[4] EVP provides nearly immediate service for emergency vehicles by interrupting the normal cycling of a traffic signal in favor of an emergency vehicle. These technologies have continued to evolve over the past 30 years.

Turning to air transport (HEMS), in 1991 there were approximately 225 helicopters dedicated to air medical service. That number has grown substantially to over 800 helicopters, transporting 400,000 patients annually.(77) The resulting flight hours have grown from 162,000 (1991), and in 2005 the number of HEMS flight hours exceeded 300,000 hours.(78) Between 1998-2008, there were 141 HEMS accidents, of which 48 were fatal crashes involving 128 deaths.(79) Of this total, Helicopter Association International reported that 76% were a result of pilot error. These errors can be broadly categorized as poor pilot technique; lack of situational awareness; loss of control; poor aeronautical decision-making; controlled flight into terrain, water or objects and combinations thereof.(80)

As a result of HEMS safety concerns, The National Transportation Safety Board (NTSB) conducted a special investigation of EMS safety focusing on air safety (2006).(81) It found that technology could improve safety performance:

> *During low flight over terrain or flight over variable terrain, the use of terrain awareness and warning systems (TAWS) could provide valuable information to pilots who are trained in instrument flight but do not completely or properly use all of their instruments, as well as those pilots who are not instrument-trained. TAWS can substantially reduce pilot workload and improve the margin of safety during limited visibility conditions, which are often encountered during EMS operations. (p.11)*

A more recent report by GAO (2009) reinforced the potential value of technologies to improve air EMS safety.(82) They supported increased use of TAWS commenting on its dramatic impact, and noting its adoption on large passenger carriers. They also commented on the potential for night vision goggles to improve safety. These findings suggest that technology can be a part of enhanced safety for air EMS as well.

FINDING: A new generation of skills is required to design, implement, and manage the EMS Continuum of Care.

Technology is changing from a "tool" concept to a "team member" concept. To take advantage of the benefits, technology should be considered as part of an integrated team to deliver clinical care to patients rather than merely as a gadget, device, or required procedure. In this role, technology is a participant in intelligent decision making that provides guidance on clinical protocols and procedures, transportation navigation, crew scheduling and placement, inventory control and management, situational awareness, and more. Increasingly, technology is becoming a less noticeable participant, as in the example of automated crash avoidance systems and advanced driver assistance systems.(83, 84) Crash avoidance systems may not typically be thought about by a driver or passenger on a regular basis, and do not require human interaction at the time they are activated, yet nonetheless provide important safety capabilities. In this environment, there is a need for a higher degree of technology awareness and a new set of technology skills and appreciation in EMS.

Long range organizational trends include an increasing number of organizations using chief information officers (CIO's) and chief digital officers (CDO's) to provide digital leadership in strategy, operations, products and processes. Such a position at all levels of EMS (local, regional, state) would better enable organizations to choose, plan for, and implement the most effective tools and services across the Continuum of Care and core data driven activities (85), as opposed to relying on consultants and vendors as the primary sources for technological expertise. Over time, such skills and expertise could be integrated into existing EMS organizational functions, while some organizations will see a clear benefit in taking more immediate action.

There has been general recognition for the needs and skills for the EMS workforce.[86] A 2011 report "The Emergency Medical Services Workforce Agenda for the Future"[87] identifies the following four components critical to developing an EMS workforce that will thrive and be a driving force for achieving integrated, community-based EMS systems:

- health, safety and wellness of the EMS workforce
- education and certification
- data and research
- workforce planning and development

The rise of digital technology affects each of these four dimensions of the EMS workforce. For example, in terms of health, safety and wellness, it is critical that new technologies be safely integrated into the workflow of EMS processes, and that the available technologies be implemented that will maintain workforce safety. In terms of education and certification, use of technology is becoming a critical skill set and the EMS workforce will need to be trained in using these new EMS technologies. Furthermore, new educational technology such as high fidelity simulation, augmented reality, virtual worlds, and gaming may enhance education and verification of psychomotor competency.[88] Understanding data and the importance of evidence to drive operations and clinical care are at the crux of assessing and planning next generation EMS systems. Workforce professionals that can use analytical systems to derive meaningful evidence for EMS system planning will be highly valued. Yet, EMS also risks losing such individuals to higher paying industries.

A wide range of technical capabilities are needed in the next generation EMS workforce. Some of these include the ability to:

- Learn and integrate technologies into education and clinical care
- Analyze operational processes and workflows
- Administer, mine, clean, extract, and analyze data
- Manage and secure mobile computing devices
- Manage adherence to changing security and privacy guidelines
- Manage vendor software and service contracts and service level agreements
- Assess inventory utilization and control
- Administer billing systems
- Troubleshoot hardware and software issues
- Communicate technology requirements to software developers
- Integrate data across various systems

While many of these skills are desirable for EMS organizations, it is also important to note that the EMS workforce is lacking in this regard. The "EMS Education Agenda for the Future" (2000) notes core content areas in "communication" and "documentation.[87, 89]" In the "National Emergency Medical Services Education Standards" instructional guidelines, educational content on communications largely revolve around radio communications, with a limited amount of content focused on modern mobile computing devices, patient and incident documentation, and data reporting and transmission.[89] Educational curriculum standards should evaluate the extent to which technologies are discussed and taught and seek to appropriately expand the focus.

Considerations and Strategies for the future of Digital Technologies in EMS

The following are suggested strategies that the EMS community could address in order to further define, analyze, test, and build a modern digital infrastructure for EMS.

CONSIDERATION: Define "Meaningful Use" of EMS information technology.

Medicare has shaped the provision of EMS through policies requiring patient transport for payment, a practice other payers have followed. This static reimbursement model does not directly incentivize using new technologies (including technology assisted care procedures) as is currently being done in the healthcare sector in the U.S. As such, technology is often viewed as a non-reimbursable expense that must be paid for using limited public funds and grants, or through very careful financial justifications at the local EMS level. For example, in 2008, a recommendation was made to congress for "Greater coordination, investment, and utilization of telemedicine technologies for both day-to-day and emergency response.[(34)] To date, telemedicine consultations and diagnostic device usage are not reimbursable for EMS, yet several forms are reimbursable for healthcare.

In contrast, the incentives to adopt technology are clear for the healthcare system. Under the Health Information Technology for Economic and Clinical Health (HITECH) Act, eligible health care professionals and hospitals can qualify for Medicare and Medicaid incentive payments when they adopt certified electronic health record (EHR) technology and use it to achieve specified "meaningful use" objectives.[5] Four regulations have been released, two of which define the "meaningful use" objectives that providers must meet to qualify for the bonus payments, and two of which identify the technical capabilities required for certified EHR technology. Any similar adoption of these regulations for EMS should be considered in combination with larger reimbursement model changes so as to ensure that financially constrained EMS systems do not become even more overburdened.

The importance of defining what "meaningful use of information technologies" means for EMS is critical for guiding technology choices and implementations, making use of effective technologies, and avoiding those that do not result in improvements. However, it is important to note that the path to defining "meaningful use" for EMS may be different than the one taken by healthcare at large. EMS has experienced success at implementing technical standards and requirements for using them (i.e., NEMSIS) without sweeping Federal legislation and incentives. This has been accomplished through the development of partnerships and collaborations over the past decade. It is likewise important to note that the timeline for creating and adhering to NEMSIS architecture has been much longer than the HITECH act has allowed for healthcare organizations. In any case, the focus here is on the need to further define how EMS will benefit from the use of information technologies in the future.

Specific Strategies:

- *Determine what "meaningful use" of information technologies means for EMS emergency and non-emergency patient care activities.*
- *Analyze how EMS organizations can be most appropriately incentivized for meeting EMS IT meaningful use definitions.*
- *Explore feasibility of discussing meaningful use of information technology and associated implications with Office of the National Coordinator for Health IT, U.S. Department of Health and Human Services.*

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[5] See http://www.healthit.gov/policy-researchers-implementers/meaningful-use

CONSIDERATION: Support existing, developing, and emerging EMS delivery models.

There is a need to promote utilization of technology for full EMS Continuum of Care delivery models. As suggested by the business model scenarios outlined previously, there are several distinct existing and future delivery models: 1) community based care and health delivery not requiring transport, 2) emergency response not requiring transport, 3) emergency response requiring transport to ED location and, 4) EMS response requiring transport to non-ED location. In each of these scenarios, digital technology can play an important enabling role in service delivery. Looking ahead, getting patients to the appropriate level of care can become a key economic driver to EMS and thus places digital technology in the important role of delivering the value of patient care, while avoiding risk and unnecessary ED visits.

Specific Strategies:

- *Investigate digital architecture options that could support multiple EMS service delivery models and facilitate data-driven real-time decisions for each delivery model.*
- *Investigate mobile technology solutions to support community paramedicine that are customizable to key health conditions of interest and concern to local health providers (e.g. cardiac, stoke).*
- *Determine potential applications across the EMS Continuum of Care for telemedicine-supported emergency and non-emergency* responses.

CONSIDERATION: Strengthen Prehospital to Hospital communication.

In 1966, the "Accidental Death and Disability," authors wrote, "Although it is possible to converse with the astronauts in outer space, communication is seldom possible between an ambulance and the emergency department it is approaching." The situation has certainly improved since that time. Yet, this critical intersection (prehospital to hospital) continues to be a point of communication breakdown. Essential patient and incident information is often not available to ED practitioners when they need it. For example, a national survey showed that a patient care record is available for ED physicians for less than 50% of EMS patients. [37] In addition, in 2010, 23 of 48 (48%) reporting agencies had a requirement to leave a formal copy of the EMS patient care report with the patient's receiving healthcare provider at the time of transfer. [17]

The ePCR could readily evolve into an information storage and transmission hub, an enterprise system that enables true event collaboration and parallel and concurrent usage across providers. Advancements in this regard would allow data from various sources (dispatch, non-transport agency, transport agencies, transfer points) to contribute information that could be accumulated and passed along to other providers along the EMS Continuum of Care in more real-time. While a greater degree of collaboration and integration with other information systems has become possible in recent years (e.g., EHRs, Trauma/Stroke/STEMI Registries, public safety agency databases, vital statistics offices, public health registries), wide scale implementation of these advanced features is lagging.

Furthermore, diagnostic and medical device data are not consistently captured and transmitted across EMS systems. For example, in most situations where an ECG, pulse oximetry data, or point of care ultrasound images can be captured and transmitted, each is sent to a separate interface in the ED – and often not associated with an electronic PCR. These transitions in care are where the heaviest risks of information loss occur, often leading to patient and practitioner safety challenges.[42, 90] Technology needs to be designed in a manner that makes these transitions seamless.

Specific Strategies:

- *Assess best practices, needs, and future directions for enabling more data rich, real-time information handoffs from 911 to non-transport EMS and/or ambulance service; non-transport paramedic to transport paramedic; transport paramedic to destination facility.*
- *Facilitate the ED community to define, on a broad scale, what prehospital information they want to see, how they want to see it, and when they want to see it for each episode of care.*
- *Create a working group to assess best practices, needs, and future directions for more seamless integration of prehospital data with hospital, public safety, public health, and other pertinent data systems.*
- *Create a report on technology and prehospital transport applications and opportunities for rural hospitals.*

CONSIDERATION: Include EMS in transportation research and reporting from a transportation perspective.

As noted earlier, EMS is a relatively small but vital form of transportation. An estimated 28 million patient transports were conducted in 2009.[17] While modest in comparison to other modes, it is performing a life critical function for many of these patients, including the aforementioned 2.3 million MVC transports. Intelligent transportation systems (ITS) and other technologies, including connected vehicles, being developed for surface transportation need to include the safety and operational needs and interests of EMS. Significant strides have been made to assess and enhance the safety of ambulances and EMS use of the transportation system and these efforts may be further advanced through stronger ties with ITS, transportation, and transportation safety efforts.

Specific Strategies:

- *Consider an annual EMS transportation report summarizing EMS performance from a transportation perspective.*
- *Consider guidance to State DOT's for including EMS in State Highway Safety Plans and Highway Safety Improvement Plans, including guidance on use of federal funds for technology testing.*
- *Explore federal technology testing opportunities with ITS program that addresses unique EMS transport issues, as well as implications and interactions with other ITS programs.*
- *Consider full EMS Continuum of Care in technology development initiatives, including innovative prevention strategies for all transportation users (e.g., motorists, pedestrians and bicyclists).*
- *Explore creation of a public annual EMS transportation safety report, including trends, conditions and recommendations.*

CONSIDERATION: Create new technology-centric EMS education and training modalities.

The "EMS Education Agenda for the Future" (2000)[87] notes core educational content areas in "communication" and "documentation." In the "National Emergency Medical Education Standards" instructional guidelines,[89] educational content on communications largely revolves around radio communications. While some standard content is also focused on modern mobile computing devices, patient and incident documentation, and data reporting and transmission, educational institutions are largely left to pick and choose which, if any, technologies are included in their educational curricula.

Educational and training institutions could evaluate the extent to which a variety of technologies are integrated into a wide range of existing educational content areas, as well as consider including topics relating to the selection, management, and use of EMS information technologies into their curricula. Such action may improve the likelihood that professionals become engaged in operational and technology improvement initiatives once they are integrated into the workforce. For example, many industries hold regional user groups where vendors provide regular training exercises and users provide peer support and feedback on how technology can and should be improved.[(91)] Such partnerships should become more prevalent in the EMS profession to ensure that the EMS voice is heard in the design and implementation of future technologies.

Appropriate EMS training in digital technologies is critical to its success. This is true at the operational level where EMS personnel need to integrate digital technologies into their workflow in a manner that enhances and does not detract from patient care. It is also true at the management level, where EMS and health care managers need to integrate such systems into associated management information systems (MIS) and Health information technology systems that are used to track, guide, and assess performance. For example, Chief Information Officer, or "CIO" forums where upper managers gather to discuss the latest trends, developments, and best practices for using technology to solve big problems - are commonplace in many industries.

Medical and diagnostic devices that are data enabled, such as ultrasound, also need attention. These devices are not typically incorporated into training programs and thus a process is needed to determine which devices should be taught and when. Certification processes are needed for using new devices in EMS. A significant challenge is that completely new technologies require outside expert education rather than the "Sr. Medic training the Jr. Medic" model. Thus, more formal education is required for teaching and certifying competency in new technology dependent procedures and processes.

Finally, there is a need to take advantage of technology enabled learning systems. Educational games, simulations, and mobile, video-based "micro-lectures" are a few examples that have received attention.[(92)] The prospect of using technology in the classroom has been explored.[(93)] On the latter, EMS personnel (and patient care) could benefit from acquiring "just-in-time" knowledge and skills about very specific procedures, protocols, policies, and other content at critical juncture points – such as in the vehicle enroute to a patient with a condition rarely encountered by the dispatched paramedic. This may have significant impact for professionals that work infrequently in the field or for dealing with low frequency high criticality conditions.

Specific Strategies:

- *Devise training models for new technology use within the EMS/ED practice that includes workflow training and use of technology during patient care.*
- *Design training models for new technology use for EMS/ED leadership, including techniques for planning, designing, implementing and managing new information systems.*
- *Develop technology curriculum to be integrated into formal EMS education, training, and certification programs.*
- *Assess how to incorporate consumer and practitioner medical, monitoring, and diagnostic devices and "apps" into EMS training and certification curricula.*
- *Investigate the demand for a micro-lecture series of training modules that can be accessed on any web enabled mobile device.*
- *Initiate EMS technology forums for sharing best practices, vendor, and peer-to-peer training.*

CONSIDERATION: Support applied research of EMS information technology.

Certainly "Information systems should readily support ongoing systems evaluation and EMS-related research. This is necessary if the cost-effectiveness of EMS is to be determined.[2]"
While more research is needed on EMS generally, and information systems provide an essential foundation to do so, there is also a need for research into the issue of EMS information technology itself. Drawing from funded research opportunities in the area of health information technologies, key research areas include:

- Research on the acceptance, utility, challenges, and overall impact of information technologies on EMS operations and service delivery.
- Research on methods to improve information systems infrastructure and tools for conducting EMS research.
- Investigate how new and emerging technologies might create process efficiencies, new decision models (and algorithms), impact care delivery, and patient and EMS practitioner safety.
- Investigate, develop, and test new technology innovations through pilot testing with EMS partners.
- Conduct studies on meaningful ways to improve the efficacy of existing technologies to provide an evidence base for using (or not using) those technologies in the field.[6]

Little research based evidence exists on how the emerging concepts discussed previously in this report (e.g., new mobile devices and apps, social technologies, big data analytics, and new forms of cloud computing) could enable benefits to the EMS profession. Rather, new vendor technologies are implemented by forward thinking EMS leaders who learn by "trial and error" often without conducting thorough research evaluations. Supporting research efforts in this regard would provide a bridge to discovering technology benefits for EMS.

Specific Strategies:

- *Identify core research areas on EMS information technologies.*
- *Conduct applied research and evaluations on the operational and health benefits of EMS information technologies.*
- *Investigate further development of research funding partnerships with major research organizations (e.g., NIH, NSF).*

CONSIDERATION: Investigate big data intelligence opportunities for EMS.

EMS has barely scratched the surface on what could be done with data in "real time." Rather, the majority of efforts have been on collecting data for retrospective studies and comparative analyses, which is an essential precursor to advanced analytical capabilities.[59, 94] An additional precursor is the ability to link data across the Continuum of Care and with hospital systems, registries, and other public health, public safety, and transportation databases. Such linkage for conducting research and analysis continues to be a challenge. In 2011, less than 50% of the States currently link EMS data to other healthcare care systems. A total of 20 States (41%) link EMS data with Trauma Registry data, 15 States (31%) with Motor Vehicle Crash data, 13 (27%) with Emergency Department data, and 10 (20%) with Hospital Discharge data. EMS data linkage with stroke registry, STEMI registry, medical examiners, vital statistics, and/or other databases were rare'.[17]

[6] See for example: http://grants.nih.gov/grants/guide/pa-files/PA-12-196.html, http://grants.nih.gov/grants/guide/pa-files/PAR-08-268.html, http://grants.nih.gov/grants/guide/pa-files/PA-11-198.html

The EMS system produces an enormous amount of data on the EMS system, and uses a wide range of peripheral information within its daily operations. Meteorological, traffic, news feeds, and social media feeds are among the largest growing data types in the world. Many opportunities exist to use these new data resources to derive near real-time epidemiological, safety, performance, predictive, and trending insights. Big data intelligence is bringing advances to most industries and EMS can benefit from the rise of these analytical tools. To capture these benefits, there is a need for a forum for discovery and development of "intelligent" EMS. The true power of regular and timely linkage across these various data sources has yet to be tapped. The data supports the potential to create automated, intelligent systems.

Specific Strategies:

- *Explore possible data sets and types that are currently used across the EMS Continuum of Care, and potential data sets and types that are peripheral to EMS, yet could provide value to EMS (transportation, health, economic, geospatial, weather, etc.). Assess the potential uses and value of each for Big Data analysis.*
- *Create EMS test sites with identified traditional and non-traditional data elements inclusive of a wide range of datasets, and utilize these for Big Data concept testing and EMS algorithm development.*
- *Research, design and test a cloud-based EMS Data Repository, inclusive of datasets identified above, that could be used regionally by practitioners and researchers to analyze EMS performance and trends.*
- *Create a National EMS Data Intelligence Working Group to advance national and regional data analysis practices.*
- *Develop and promote model state legislation that eliminates barriers to and protects information yielded by records linkage across multiple databases.*

CONSIDERATION: Analyze new sources and uses for information across the EMS Continuum of Care, including associated benefits and risks.

Several technologies related to mobility require deeper attention in terms of their potential benefits and challenges. First, a wide range of consumer devices and applications have already hit the marketplace for monitoring and managing, for example, blood sugar levels, cardiac health, asthma and a wide range of chronic conditions. Some of these have sensors and automated data collection mechanisms, while others require manual data entry. Many have predefined thresholds that sound alerts when those thresholds are breached. Many questions arise from the prospect of such consumer empowerment. EMS should take a leadership role, to define standards for the devices and apps, protocols for their approval, and how they should (or shouldn't) interface with EMS information systems. Much of this work may be conducted together with other federal agencies, including the Federal Communications Commission (FCC), Federal Drug Administration (FDA), Health and Human Services (HHS), and the Department of Homeland Security (DHS). Work has already begun with the recent release of FDA guidance for mobile devices and apps.[(33)] EMS is already involved in determining how devices should interface with NextGen 911 and in defining EMS specific marketplace apps for use across FirstNet. A wide range of activities is required to ensure mobile application safety and efficacy, and EMS could take a leadership role to bridge public safety and healthcare on these matters to guide the future impact of these technologies across the Continuum of Care.

Second, there is a need to assess the mobile places where technology is most often used in EMS. For example, one important space is the ambulance. While attention has been given to the design of ambulances for improved safety, an important activity would be to ensure technologies can be well integrated with the processes and work performed in these spaces. Such an evaluation should not only consider technology use to improve efficiency, but also the human impacts – notably, the safety of personnel.

Third, a wide array of new medical devices, technology assisted devices, and monitoring devices are entering the marketplace for practitioner use. These devices are data enabled, providing voice, video, and/or data. For example, handheld point of care ultrasound has been explored and used in some EMS systems in the US and Europe; and patient care benefits have been discussed in the literature.[95, 96] These devices could stream a live video feed or send a still picture to a range of other devices and systems across the EMS Continuum of Care. Video assisted laryngoscopy could also send a video feed, as could a wide array of other devices. This information may be essential to capture for patient care, quality assurance, and research purposes. Furthermore, wearable technologies are entering the consumer marketplace, paving the way for wearable practitioner technologies to shortly follow (see for example, http://www.google.com/glass/start/). These devices will impact the work of EMS professionals and should be carefully assessed to determine their benefits and drawbacks prior to wide scale deployment.

Specific Strategies:

- *Conduct an assessment of the impact of consumer-owned mobile health computing on EMS and the role of EMS leadership in providing guidance and business use cases.*
- *Evaluate ambulance guidelines for optimal technology integration for using information technologies in the rig and for ensuring driver and passenger safety.*
- *Conduct an assessment of the impact of practitioner oriented medical devices and mobile computing devices and their associated data on practitioner safety, efficiency and patient care.*
- *Conduct a thorough "EMS Information Systems Agenda for the Future" that builds upon the original Agenda and expands upon the concepts presented in this report.*
- *Perform a synthesis of technology and data uses designed, evaluated, or deployed for other transportation modes such as commercial vehicles and transit for applicability to and utility in EMS.*

CONSIDERATION: Actively support open standards and protocols development, including for mobile applications and devices.

The EMS community has been actively engaged in standards development for many years. Indeed, NEMSIS stands as a success story in how partnerships can be utilized to create a set of standards and how these efforts can continue to be refined, updated, and expanded over time according to the needs of the community. EMS has also participated and led a wide range of public safety and 911 standards development initiatives. There is widespread agreement that implementation of "open" data systems is important to enabling the Continuum of Care. Transmitting data from one system to another makes sense for patient care. Yet, challenges continue to exist in the closed design of many vendor software systems and institutional cultures. The EMS community would benefit from learning about the benefits of open systems for more seamless exchange of data.

There is a need for specific vendor "device" standards and protocols that can be accessed at the point of care. For example, as alluded to previously, practitioners need to know how they should respond if a patient has a medical or mobile device or app, such as a left ventricular assist device (LVAD) by vendor A, with product version Z. Practitioners need a means to assess the validity of data produced from devices and apps, and instructions on how to manage a wide range of specialized medical devices. Such information could exist in a database accessible via a mobile device. Perhaps a future solution would be for the device to "tell" EMS personnel what it is and what to do in the case of an emergency.

An important goal for EMS could be to require new devices to be data enabled and have open interfaces to collect that data. However, just as above, there is a need for new ways to inform the EMS community about protocols for dealing with devices and manufacturers. For example, if a patient enters the ED with a new advanced pacemaker, for which a physician has had no experience working, there must be a better method to "figure it out" than to call the vendor to troubleshoot the device. There is a need for standardization of these devices. Blood sugar variance across vendor devices is also significant. With some devices reading high, and others reading low on the same measure, there is no way to accurately compare readings.

We not only need standardization of low level data elements, but also for how those data are being used to produce outputs. Secondary and tertiary level data needs to be standardized so we know how that data are being produced. For example, agreement is needed across the medical community on universally accepted scoring systems (e.g., trauma). Scales and scoring systems are key precursors for gaining value out of data systems. These scoring systems often provide valuable frameworks that form the basis for algorithms – which can be combined with other data sources and used to develop software based systems to assess a patient's health condition.

Standard protocols are also needed for the regular extraction and reporting of data. Paramedics typically do not know what happened to their patients. The feedback loop doesn't exist because the required mechanisms are not in place.

Specific Strategies:

- *Continue involvement in technical and data standards development activities, including critical infrastructure cybersecurity initiatives.*
- *Form an EMS "open data" forum to progress open data, architecture, and systems thinking across the profession.*
- *Create working group to standardize common EMS care protocols and provide the foundation for building analytical decision support protocols.*
- *Assess EMS information needs relative to standardization of specialized and implantable devices.*
- *Assess EMS information needs relative to standardization of consumer and practitioner mobile devices and "apps".*
- *Actively support ongoing mobile applications, device standards and protocols development for EMS, including participation in defining how both consumer and practitioner mobile apps and devices can most effectively be integrated, validated, secured, and utilized in EMS.*

Conclusion

Taken together, these findings and considerations suggest that there is considerable value in launching a new generation—a new "Agenda" of EMS technology research, testing, and deployment, provided it is aimed at enhancing the performance of EMS across the full Continuum of Care. The promise of continuous improvement in EMS relies heavily upon medical and information technologies, and the opportunity is now for the EMS community to define and engage in designing its future.

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Appendix 1

Subject Matter Experts

1. Bryan Bledsoe, DO, FACEP, FAAEM, EMT-P, Professor, Director of EMS Fellowship, Department of Emergency Medicine, University of Nevada School of Medicine; Medical Director, MedicWest Ambulance; Medical Director, Burning Man
2. Jay English, Director, Communication Center & 9-1-1 Services, APCO International
3. Laurie Flaherty, RN, MS, U.S. Department of Transportation / National Highway Traffic Safety Administration, Office of Emergency Medical Services
4. Dia Gainor, MPA, Executive Director, National Association of State EMS Officials
5. William Hinkle, Senior Vice President, Strategic Industry Relationships, Intrado
6. Barry J. Knapp, M.D. FACEP, RDMS, Associate Professor, Program Director, Department of Emergency Medicine, Eastern Virginia Medical School
7. Kevin McGinnis, MPS, EMT-P, FirstNet Board Member, Technology Advisor to: National Association of State EMS Officials, National Association of EMS Physicians, National Association of EMTs, National EMS Management Association, National Association of EMS Educators
8. Kathy McMahon, Director of Public Safety, Agero
9. Greg Mears, MD, Medical Director, Zoll Medical Corporation; Medical Director, Emergency Performance Inc.
10. Nick Nudell, MS, NRP, Partner, PrioriHealth Partners, LLP
11. Paul Patrick, Director, Utah State EMS Bureau
12. Shelley Row, Shelley Row Associates
13. Deborah Stuck, MD, Fairfield Medical Associates
14. David Tucker, Executive Director, Vermont Enhanced 911 Board
15. Gary Wallace, Vice President, Corporate Communications-Government Affairs, Agero
16. Gary Wingrove, Director, Government Relations & Strategic Affairs at Gold Cross/Mayo Clinic Medical Transport

Appendix 2

From the 1996 EMS Agenda Report

The year is 2009 and it's a Thursday evening. Joe S. is a 60-year-old male who emigrated from Russia in 1995 *to work for a software company. He does not speak English very well. He has several cardiac risk factors including hypertension, elevated cholesterol, a history* of smoking *(a pack a week), and he is 20% overweight. For the past two days he has* had *mild, intermittent chest discomfort unrelated to exercise. However, at 11:OO PM, the discomfort suddenly becomes more severe. Joe's wife, worried and anxious, instructs their computerized habitat monitor (CHM)* to *summon medical help. Through voice recognition technology, the CHM analyzes the command, interprets it as urgent, and establishes* a *linkage with the appropriate public safety answering center (PSAC). At the PSAC, a "smart map" identifies and displays the location* of *the call. Richard Petrillo, the emergency medical communicator (EMC) notes the type* of *linkage that has been established (not a telephone, personal communicator device, television,* or *personal computer). He also knows what sort of query can be conducted through this linkage. Petrillo commands the PSAC computer to instruct the CHM to identify the potential patient, report his chief complaint, and provide* his *medical database identifiers. In the meantime, the "smart map" has identified the closest acute care response vehicle and Petrillo instructs the computer to dispatch it. The CHM provides the requested information and responding personnel are automatically updated via their personal digital assistants (PDAs). Petrillo accesses the patient's health care database, obtaining his current health problem list, most recent electrocardiogram, current medications, allergies, and primary care physician data. This information automatically is copied to the responding personnel's PDAs and to the medical command center (MCC) computer. The PSAC computer also downloads pre-arrival instructions to the CHM which provides them to Joe's wife.*

Staffing the acute care response vehicle are Nancy Quam, Community Health Advanced Medical Practitioner (CHAMP) and Ed Perez, Community Health Intermediate Practitioner (CHIP). Nancy *became a CHAMP because she recognized a declining need* for *physicians. She was credentialed following a four-year college degree program. Many* of *her colleagues were previous paramedic*s *and nurses who became credentialed through career-bridging programs. Ed Perez was credentialed as a CHIP after* a *one-year academic program. He currently goes to school part-time, on a scholarship, working toward becoming a CHAMP. As Quam and Perez proceed toward Joe's home, a transponder in their vehicle* changes *alI traffic* signals *in their* favor. *Also, digital displays in all area vehicles are alerted that there is an emergency vehicle in their vicinity. The PSAC computer informs Quam and Perez that neither a personal risk analysis (PRA) nor a domicile risk analysis (DRA) has been performed in the past five* years.

As Quam and Perez arrive at the home, four minutes after the initial linkage with CHM, they notice substandard lighting on the homes outside walkways and front-porch steps in *need* of *repair. They also* note *that a maintenance light is illuminated on the CHM annunciator panel. As they greet the patient, they realize that he does not speak English well. Perez puts the translator module into his PDA, then he speaks to the PDA which translates his voice to Russian. The allsystems monitor is applied to the patient's* arm *and across his chest. Physiologic data is acquired by the monitor's computer chip, then it is analyzed on the scene and transmitted* via *burst technology to the medical command* center 100 miles *away. By* *communicating through their PDAs, Quam and Perez are able to acquire the patient's history. Through Quam's PDA video screen, she establishes a video connect with the MCC. The MCC EMS physician requests additional Level III monitoring which* reveals *the patient's carbon monoxide level to be 14%.*

Analysis of *all the data by the MCC computer and EMS physician suggests a 96% probability* of *acute myocardial ischemia. Quam and the EMS physician confer and the patient subsequently* is *administered shortacting thrombolytics and IV antioxidants. The nearest cardiac care center that is part* of *Joe's health* network *is identified and alerted by computer. Joe is transported there, even though other hospitals may be closer. He is examined very briefly in the emergency department and taken directly to the cardiac catheterization laboratory. There he undergoes* complete *laser debridement* of *his coronary arteries. Joe suffers no myocardial enzyme leak, there is no permanent cardiac damage, and he is discharged in* two *days.*

Following Quam's and Perez's report, a PRA and a DRA are requested. Joe's health care network contracts with their agency to return to the home where they learn that the *family did not completely understand the* CHM's *operations. Thus, when its carbon monoxide sensor had failed they were unaware. The health care network subsequently offers a matching* grant *to repair an aging furnace, the CHM, and the other environmental hazards noted by Quam and Perez. In follow-up, it was determined that Joe had been noncompliant with his previous medication instructions due to lack* of *understanding. A new caseworker is assigned who ensures that Joe understands his health care instructions and begins to minimize all his risk factors. Joe lives* to 94 *years old.*

Appendix 3

Description of Technologies Listed in Figure 2

Computer Aided Dispatch (CAD): A software based system used to complete public safety and EMS calls for service, dispatch, communication with and monitoring of responding resources in the field. It is used by emergency communications dispatchers, call-takers, and 911 operators in public-safety answering points (PSAPs) to notify field personnel and maintain communications. CAD data is used by EMS to initiate a response, find the emergency incident location, understand the reported disposition of callers and patients at the scene prior to arrival, and to track and monitor emergency response performance over time.

Consumer Medical Monitoring Devices: A medical monitoring system includes at least one patient medical apparatus, owned by the consumer/patient, for monitoring at least one aspect of a patient's physical condition and generating at least one variable signal in response to the monitoring. For the purposes of this paper, a medical monitoring device is a computing system that can provide data on its purposeful output.
According to the FDA, a medical device is an instrument, apparatus, implement, Machine, contrivance, implant, in vitro reagent, or other similar or related article, including any component, part, or accessory, which is—

• recognized in the official National Formulary, or the United States Pharmacopeia, or any supplement to them,
• intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or
•intended to affect the structure or any function of the body of man or other animals, and which does not achieve its primary intended purposes through chemical action within or on the body of m an or other animals and which is not dependent upon being metabolized for the achievement of its primary intended purposes (21 U.S.C. 321(h)).

See: http://www.fda.gov/downloads/RegulatoryInformation/Guidances/UCM127067.pdf

Consumer Mobile Health Apps: Refer to mobile apps used by consumers (as opposed to healthcare providers). These are software programs that operate on a mobile computing device, including a laptop computer, tablet computer, SmartPhone, or other mobile communication device. They can also be accessories that attach to a smartphone or other mobile communication device, or a combination of accessories and software.

Mobile medical apps are medical devices that are mobile apps, meet the definition of a medical device as defined by the Food and Drug Administration (FDA), are an accessory to a regulated medical device, or transform a mobile platform into a regulated medical device. Consumers can use both mobile medical apps and mobile apps to manage their own personal health and wellness, such as to monitor their caloric intake for healthy weight maintenance. For example, the National Institutes of Health's LactMed app provides nursing mothers with information about the effects of medicines on breast milk and

nursing infants. Other apps aim to help health care professionals improve and facilitate patient care. The Radiation Emergency Medical Management (REMM) app gives health care providers guidance on diagnosing and treating radiation injuries. Some mobile medical apps can diagnose cancer or heart rhythm abnormalities, or function as the "central command" for a glucose meter used by an insulin-dependent diabetic patient.
See also:
http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/ConnectedHealth/MobileMedicalApplications/default.htm

Electronic Health Record (EHR): An electronic health record (EHR) is a digital version of a patient's paper chart. EHRs are real-time, patient-centered records that make information available instantly and securely to authorized users. While an EHR does contain the medical and treatment histories of patients, an EHR system is built to go beyond standard clinical data collected in a provider's office and can be inclusive of a broader view of a patient's care. EHRs can:

- Contain a patient's medical history, diagnoses, medications, treatment plans, immunization dates, allergies, radiology images, and laboratory and test results
- Allow access to evidence-based tools that providers can use to make decisions about a patient's care
- Automate and streamline provider workflow

One of the key features of an EHR is that health information can be created and managed by authorized providers in a digital format capable of being shared with other providers across more than one health care organization. EHRs are built to share information with other health care providers and organizations – such as laboratories, specialists, medical imaging facilities, pharmacies, emergency facilities, and school and workplace clinics – so they may contain information from all clinicians involved in a patient's care.
See: http://www.healthit.gov/providers-professionals/faqs/what-electronic-health-record-ehr

Electronic Patient Care Record (ePCR): The ePCR is a pre-hospital electronic health record inclusive of data from an EMS incident and patient care episode. EPCRs may include data from dispatch, EMS personnel (non-transport and transport EMS), and medical devices. Many commercial ePCR systems adhere to the NEMSIS data standard for local, state, and National reporting of EMS data.
See also: http://www.nemsis.org

Geographic information systems (GIS) (Electronic Maps): A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows individuals to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Google Maps have popularized the GIS concept.
See also: http://www.esri.com/what-is-gis/overview#overview_panel

Health Information Exchange (HIE): Health Information Exchange (HIE) allows health care professionals and patients to appropriately access and securely share a patient's vital medical information electronically across a region of health care providers, effectively sharing information across a wide range of providers—with the goal of improving the speed, quality, safety and cost of patient care.
See also: http://www.healthit.gov/providers-professionals/health-information-exchange/what-hie

Highway Infrastructure and Sensors: Highways are the backbone of the American transportation system, moving the vast majority of the Nation's products and goods, and providing the vital link between all modes of transportation. Generally, for this report, the term refers to the myriad of electronic devices and sensors that are integrated into the highway infrastructure (cameras, road sensors, lights, etc.), not including vehicles, that enable intelligent transportation systems (ITS). http://www.fhwa.dot.gov/publications/research/infrastructure/structures/08068/index.cfm

Inventory Management System: Is a software suite for managing and locating objects or materials. Components may include order management (defining thresholds for automated reordering of products), asset tracking (keeping track of the location of a product, whether it be in a warehouse or on a delivery truck), service management (tracking the cost of supplies to provide services), product identification (barcodes, RFID tags, QR codes for identifying all aspects of a product), and product cost accounting.

In-Vehicle Safety Technologies: Refers to special technology developed to ensure the safety and security of automobiles, drivers, and passengers. Example technologies include crash avoidance systems, rollover avoidance and protection, and automatic crash detection and notification technologies.

Practitioner Diagnostic Devices: A medical device as described above under “Consumer Medical Monitoring Devices,” except that these devices are controlled and utilized by EMS practitioners. For example, 12 lead ECG and pulse oximetry. The focus in this report is on devices that are “data enabled.” See also: http://www.fda.gov/downloads/RegulatoryInformation/Guidances/UCM127067.pdf

Practitioner Mobile Devices and Apps: Refer to mobile apps used by healthcare providers (as opposed to consumers). See description above for Consumer Mobile Health Apps.

Real Time analytics: Real-time analytics is the use of, or the capacity to use, all available enterprise data and resources when they are needed. It consists of dynamic analysis and reporting, based on data entered into a system less than one minute before the actual time of use. Real-time analytics is also known as real-time data analytics, real-time data integration, and real-time intelligence.
See also: http://searchcrm.techtarget.com/definition/real-time-analytics

Telemedicine: Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient’s clinical health status. Telemedicine includes a growing variety of applications and services using two-way video, email, smart phones, wireless tools and other forms of telecommunications technology. Telemedicine is commonly conceptualized as providing a live stream of data for two-way broadband communications. In Figure 2, we refer to “telemedicine consultation,” including on-demand video and/or voice consultations with distributed care providers.
See also: http://www.americantelemed.org/learn

Social Media: Social media refers to the means of interacting among people across a network of friends, peers, family members, and associates. Participants typically create, share, and/or exchange information and ideas in virtual communities and networks with people that they are acquainted with, yet may also broadcast such information to interested subscribers.
See also: http://webcomm.tufts.edu/social-media-overview13/

Wearable, Voice-activated devices: Refer to computing devices that are worn by an individual user of a technology. As with the case of other mobile devices, they may include a wide range of sensors for location tracking, motion tracking, or for inputting information through cameras, voice recorders, or other sensing equipment. These may include wearable textiles, or other lightweight equipment mounted on a human body (e.g., head, arm, leg). The benefits include hands-free operation with sophisticated sensor and/or voice-activated interfaces.

Wireless Broadband: Is technology that provides high-speed, high bandwidth wireless Internet access and communications over long distances. As described at Broadband.gov, broadband service provides higher-speed of data transmission. It allows more content to be carried through the transmission "pipeline." Broadband provides access to the highest quality Internet services—streaming media, VoIP (Internet phone), gaming, and interactive services. Many of these current and newly-developing services require the transfer of large amounts of data that may not be technically feasible with dial-up service. Therefore, broadband service may be increasingly necessary to access the full range of services and opportunities that the Internet can offer. Broadband is always on. It does not block phone lines and there is no need to reconnect to network after logging off. Less delay in transmission of content when using broadband.
See also: http://www.broadband.gov/about_broadband.html

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