AUDREY Hastings Experiment
After Action Report

for

The Department of Homeland Security
Science and Technology Directorate

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Executive Summary

The U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate partnered with the National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory (JPL) to apply JPL's artificial intelligence (AI) system to first responder capability gaps. The Assistant for Understanding Data through Reasoning, Extraction, and sYnthesis (AUDREY) uses innovative reasoning systems and artificial general intelligence (AGI) technologies to perform data fusion and provide situational awareness information for first responders.

DHS S&T and Defence Research and Development Canada's (DRDC) Centre for Security Science (CSS) collaborated to conduct a field experiment applying AUDREY to a series of operational use cases in June 2019. The *AUDREY Hastings Experiment (AHE)* was held in Hastings County, Ontario (ON), with the Hastings-Quinte Paramedic Service (HQPS) acting as the principal participating paramedic response agency. The experiment tested the potential for AUDREY to improve patient outcomes by supporting assessment and treatment during medical calls. AHE was designed to both demonstrate the benefit provided by AI for emergency response operations and to foster continued cooperation between DHS S&T and DRDC CSS in the development of cross-border technology solutions.

The experiment scenario focused on the medical response to a patient complaining of chest pain. AUDREY was deployed in this scenario to assess the system's impact on decision-making quality and patient outcomes. Six use cases were developed for this experiment, each intended to assess different capabilities that AUDREY could enhance during a medical response. Each use case was comprised of five phases: Dispatch, En route, Assess, Treat and Transport (to hospital). These five phases of an emergency medical call for service were used to document the AHE results and findings.[1] By organizing the AHE results according to the phases, the areas in which AI is most ready to improve the effectiveness, efficiency and safety of operations could be identified.


Dispatch


En Route


Assess


Treat


Transport

AHE was not designed to be a product test of a fully developed system, but instead to explore how AI may enhance responder operations. Paramedics, physicians, municipal leaders and project staff were introduced to the significant prospects of AI support to operations. In addition, AHE prompted the consideration of other emergency response problems that AI could address. Although the system was not able to address all the experiment objectives as originally envisioned, AUDREY did demonstrate progress in supporting decision-making, improving

[1] The star of life is the commonly used symbol for emergency medical services (EMS). The star contains six branches that represent the main EMS tasks. The tasks identified in the star do not directly correlate with the phases used during AHE because several of the star tasks occur before or after activities during the use cases. The five AHE phases were identified by the paramedic service that supported AHE.

paramedic and patient safety, and decreasing paramedic workload. For example, automating the input of patient data (once available at a high level of confidence and accuracy) will serve as a force multiplier by returning productive hours to first responders. Further, AHE fostered the development of cross-border relationships with government entities and industry.

Patient Safety Outcomes: AUDREY aimed to improve patient safety outcomes by reducing medication errors. During AHE, physicians and paramedics alike expressed that patient safety precautions, largely confirmation of right medications, and reducing human error are critical issues that need to be addressed. During AHE, AUDREY was able to provide medication verification when the paramedic captured an image that was transmitted to AUDREY for analysis. During the experiment, there were some inconsistencies with AUDREY's ability to process and transmit such images. In addition, AUDREY was partially able to provide medication reminders for the paramedic.

Decision Support Outcomes: AUDREY is intended to provide the paramedic with information, alerts and tools to enhance their decision-making. Though results indicated that AUDREY was successful in recognizing and transcribing basic patient data such as patient age, gender and symptoms, and pulse, blood pressure, respirations, and oximetry data, its assessment capabilities were incomplete.

Information Fusion Outcomes: AUDREY is designed to assist responders in synthesizing high-level data while at an incident scene. During AHE, AUDREY was successful in recognizing and ingesting call information from dispatch and transmitting the standing orders to the paramedics. However, AUDREY seemed to face challenges with assessing the information and data and aggregating it into actionable recommendations and reports. Possibly due to speech processing and/or connectivity issues, AUDREY was not able to successfully complete a needed form with all patient data during AHE. Participating paramedics and physicians strongly agreed that having information from AUDREY that they do not currently have access to (e.g., picture of an EKG) would be extremely beneficial.

Communications Outcomes: Effective and efficient communications are important for any first responder discipline, but especially critical for emergency medical calls. AUDREY faced challenges in correctly populating forms needed for communications between the paramedic and the physician. One concern was that the patch form would still not provide enough information to the physician for him or her to make a judgment call on a treatment plan, further stating that they also need to be able to see what is happening with image and/or video data (e.g., visual defibrillator data). AUDREY demonstrated there are some aspects where AGI can benefit paramedic operations, but there are still challenges when dealing with complex cases.

Process Outcomes: With the integration of any new technology, process or system comes at least a minimal level of adjustment. During AHE, it was apparent that the participating paramedics were having trouble interacting with AUDREY. One participating physician observed that it seemed like the paramedics were having to adapt to fit AUDREY rather than the technology fitting into their current processes. Future development should actively engage

responders at the beginning to appreciate the working conditions and adapt the technology around that work environment.

Introduction

The U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate partnered with the National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory (JPL) to apply JPL's artificial intelligence system (AI) to first responder capability gaps. The Assistant for Understanding Data through Reasoning, Extraction, and sYnthesis (AUDREY) uses innovative reasoning systems and artificial general intelligence (AGI) technologies to perform data fusion and provide situational awareness information for first responders. This application of AUDREY to response operations was part of the DHS S&T Next Generation First Responder (NGFR) Apex program.

DHS S&T and Defence Research and Development Canada's (DRDC) Centre for Security Science (CSS) collaborated to conduct a field experiment applying AUDREY to a series of operational use cases in June 2019. The *AUDREY Hastings Experiment (AHE)* was held in Hastings County, Ontario (ON), with the Hastings-Quinte Paramedic Service (HQPS) acting as the principal participating paramedic response agency. The experiment examined the potential for AI to improve patient outcomes by supporting paramedic assessment and treatment during medical calls.

Explanatory Note: Emergency medical service (EMS) providers include paramedics and emergency medical technicians (EMTs). The difference is based on qualifications and education. Paramedics have a higher level of training and are subsequently authorized to perform a larger number of procedures and administer additional medications. In the United States, the majority of EMS providers are qualified at the EMT-Basic or -Intermediate level. Canada does not use the term EMT in most provinces; their EMS providers are qualified at the Primary Care Paramedic (PCP) or Advanced Care Paramedic (ACP) levels. The term "paramedic" is used throughout this report for accuracy and consistency. However, all outcomes and findings regarding the use of AI to support operations during medical calls should apply to emergency medical operations, regardless of provider title or training.

Artificial General Intelligence

Artificial General Intelligence can be defined as the ability of a machine to perform any task that a human can do.[2] In the past, AI capabilities have been applied to solving very specific problems, resulting in systems that are able to complete particular tasks far more quickly and efficiently than humans. These systems are often called Narrow AI systems because they focus on one capability and are unable to expand or change in functionality. AGI systems, on the other hand, can acquire new knowledge and skills, understand language, understand purpose

[2] Joshi, Naveen. "How Far are We from Achieving Artificial General Intelligence?" Forbes, June 10, 2019. https://www.forbes.com/sites/crowe/2019/11/01/as-global-supply-chains-tighten-spotlight-shifts-to-strategic-sourcing/#1e63ed42568a

and context, and reach conclusions. They are not restricted to performing one skill, but are able to continuously learn and adapt.[3] While complete AGI systems do not yet exist, the intent of the AUDREY Hastings Experiment was to apply AGI technologies to current operational problems and assess the impact.

Current AI systems rely on significant amounts of training data that are applied to solve problems. For AHE, AUDREY was trained using patient care standards and protocols, a substantial volume of call data, audio recordings of paramedic calls for service, and an array of images and video files. The intent was to assess how AI could improve situational awareness, paramedic and patient safety, medical outcomes, information sharing, and operational procedures.

AUDREY Overview

AUDREY is an artificial intelligence system that aims to help fill first responder capability gaps. It is an "extendable, integrated platform for transforming multimodal data into contextually relevant insight." In other words, AUDREY uses innovative reasoning systems and AGI technologies to perform data fusion and provide situational awareness information to first responders. AUDREY connects with sensors on the responder's personal protective equipment (PPE) and information provided by the Internet of Things (IoT) through a suite of plug-in tools. AUDREY is designed to intelligently consider the situation of each responder and extract key information as it pertains to their needs. Rather than immediately forwarding this information and risk distracting the first responder, AUDREY synthesizes high-level actionable information and provides it to the first responder when appropriate.[4]

Participation

Eight organizations participated in AHE including federal, local and private sector organizations.

Defence Research and Development Canada (DRDC) Centre for Security Science (CSS):

DRDC is an agency within Canada's Department of National Defence. DRDC's primary purpose is to "develop and deliver new technical solutions and advice to the Department of National Defence, the Canadian Armed Forces, other federal departments and the safety and security communities."[5] More specifically, it supports "defence and security operations at home and abroad with knowledge and technology; provides [science & technology (S&T)] to forecast, cost, and deliver future readiness levels to meet operational requirements; and generates

[3] Voss, Peter. "From Narrow to General AI." Medium, October 3, 2017. https://medium.com/intuitionmachine/from-narrow-to-general-ai-e21b568155b9

[4] "NGFR Technology Descriptions," AUDREY Hastings Experiment Plan, viewed 17 April 2019

[5] "Defense Research and Development Canada," Canada.ca, viewed 15 April 2019, https://www.canada.ca/en/defence-research-development.html

knowledge and technology for a robust, connected and multi-jurisdictional security and intelligence environment."[6]

DRDC's CSS leads (in partnership with Public Safety Canada) the Canadian Safety and Security Program (CSSP), which aims to "strengthen Canada's ability to anticipate, prevent, mitigate, prepare for, respond to, and recover from natural disasters, serious accidents, crime and terrorism through the convergence of S&T with policy, operations and intelligence."[7] CSSP "supports federal, provincial, or municipal government-led projects in collaboration with response and emergency management organizations, non-governmental agencies, industry and academia."[8] CSS also oversees numerous international agreements with the United States and the United Kingdom in order to leverage resources and foster S&T collaborations between allied nations. The role of CSS in AHE was to participate in development and execution of the experiment with the goal of supporting advances in capability for responders in Canada.

U.S. Department of Homeland Security (DHS):

The U.S. Department of Homeland Security is a cabinet department of the U.S. federal government with responsibilities in public security. Specifically, its mission is to "ensure a homeland that is safe, secure, and resilient against terrorism and other hazards."[9] Missions include: preventing terrorism and enhancing security, managing the nation's borders, administering immigration laws, securing cyberspace, and ensuring disaster resilience.[10] In addition, DHS focuses specifically on maturing and strengthening the homeland security enterprise itself.

> The DHS Science and Technology Directorate (S&T) is a component of DHS that was established with the purpose of conducting basic and applied research, development, demonstration, testing and evaluation activities relevant to DHS. Its mission is to "enable effective, efficient, and secure operations across all homeland security missions by applying scientific, engineering, analytics, and innovative approaches to deliver timely solutions and support departmental acquisitions."[11] Addressing current capability gaps while simultaneously preparing for future challenges is also an objective of S&T. The Next Generation First Responder (NGFR) Apex Program was an S&T-funded effort to develop advanced technologies for responders to keep them better protected, connected and fully aware. DHS S&T funded AHE as part of the NGFR program and as a follow-on to other U.S.-Canada technology experiments. DHS S&T project staff developed the experiment objectives, the privacy threshold assessment and master scenario events list. In addition, personnel from S&T's Human Systems Integration (HSI) provided assistance in the

[6] "Defense Research and Development Canada Mission and Impact," Canada.ca, viewed 15 April 2019, https://www.canada.ca/en/defence-research-development.html
[7] "Canadian Safety and Security Program," DRDC, viewed 15 April 2019, http://www.drdc-rddc.gc.ca/en/dynamic-article.page?doc=canadian-safety-and-security-program/hzvlql9b
[8] ibid
[9] "Our Missions," Department of Homeland Security, viewed 15 April 2019, https://www.dhs.gov/our-mission
[10] ibid
[11] "About S&T," Department of Homeland Security Science and Technology (S&T) Directorate, viewed 15 April 2019, https://www.dhs.gov/science-and-technology/about-st

development and observation of AHE, with a particular focus on human factors analysis of the technology.

The National Urban Security Technology Laboratory (NUSTL) is a DHS federal laboratory focused on evaluation and transition of homeland security technologies into field use for law enforcement, fire and other emergency response agencies. Staff experts work side-by-side with first responders to effectively plan and execute tests, evaluations, and assessments of existing and emerging technologies. NUSTL staff participated in the planning and preparation for AHE, specifically on development of the test and evaluation (T&E) plan and acted as neutral observers during the experiment.

National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory (JPL)

NASA JPL is the developer of AUDREY. JPL is a national laboratory and Federally-Funded Research and Development Center (FFRDC) that carries out robotic space and Earth science missions.[12] Specifically, JPL implements programs in "planetary exploration, Earth science, space-based astronomy and technology development," while also "applying its capabilities to technical and scientific problems of national significance," like first responder capability gaps.[13] JPL staff were responsible for training AUDREY and developing the capabilities needed to meet the AHE objectives.

U.S. Department of Energy (DOE) Pacific Northwest National Laboratory (PNNL):

The U.S. Department of Energy (DOE) is a cabinet department of the U.S. federal government that focuses on energy and safety policies. Its overarching mission is to discover the solutions to power and to secure America's future. This is accomplished by working to advance national economic, energy and security goals through scientific and technological innovation. The Pacific Northwest National Laboratory (PNNL) is a research institution with strengths in chemistry, earth sciences and data analytics. The PNNL-developed VitalTag system was used to provide patient data during a set of AHE use cases.

Hastings-Quinte Paramedic Service (HQPS)

The Hastings-Quinte Paramedic Service (HQPS) is headquartered in Belleville, ON (Hastings County), and provides direct ambulance service from six base locations and one post around the county. HQPS delivers services to a population of approximately 170,000 (including Hastings County, Quinte West, as well as neighboring Prince Edward County). Its service commitment to this population is to respond within two minutes of receiving notification of an emergency.[14] The HQPS Chief provided substantive input to the planning and development of AHE and HQPS provided advanced care paramedics to participate in the experiment.

Interdev Technology Inc.

Interdev Technology Inc. provides Software as a Solution (SaaS) for paramedic services and other healthcare providers in Canada, including Hastings County. Interdev implements and maintains every component of the infrastructure, hardware, software, security, storage, data

[12] "Jet Propulsion Laboratory," NASA, viewed 15 April 2019, https://www.jpl.nasa.gov/news/fact_sheets/jpl.pdf
[13] ibid
[14] "Emergency Services," Hastings County, viewed 15 April 2019, http://www.hastingscounty.com/services/emergency-services

and analytics required for its solutions. Its solutions integrate data from several different sources (e.g., CADlink [computer aided dispatch], global positioning system, defibrillator). Interdev users can see the analytics of their data in order to deconstruct and audit key performance indicators (KPIs). Interdev's iMedic Gen II is used to capture and share information associated with paramedic calls; electronic patient care records (EPCR) are generated through this software package.[15] Interdev provided training data for JPL use in the development of AUDREY, as well as formats to enable data exchange between their systems and AUDREY. The company supported AHE by using its capabilities to fulfill the typical dispatch system role and provide scenario-relevant data.

Regional Paramedic Program for Eastern Ontario (RPPEO)

The Regional Paramedic Program for Eastern Ontario provides certification and authorization, continuing medical education, and medical oversight, advice, and consultation to ambulance services and their paramedics.[16] RPPEO provided subject matter expertise and guidance during the planning and execution of AHE.

[15] ibid

[16] "RPPEO: Our Mandate," Regional Paramedic Program for Eastern Ontario, viewed 31 January 2020, https://www.rppeo.ca/home/our-mandate.html

AUDREY Hastings Experiment (AHE)

AHE was designed to demonstrate the benefit provided by AI for emergency response operations and to foster continued cooperation between DHS S&T and DRDC CSS in the development of emergency response technology solutions. Following on the Canada-U.S. Enhanced Resiliency Experiments (CAUSE) series, AHE continued this cross-border collaboration to focus on the operational challenges faced by medical responders in the United States and Canada.

Objectives

Stakeholders agreed on a set of five objectives in advance of the experiment. The objectives were designed to illustrate the potential benefits to paramedics during a routine call for service. Table 1 lists those objectives.

Table 1. AHE Experiment-Level Objectives

1. Validate that AUDREY can integrate and transmit emergency response data;
2. Validate that AUDREY can provide operationally-relevant data;
3. Demonstrate improved patient care outcomes for paramedic service operations;
4. Measure the increase in relevant information available to responders; and
5. Assess the utility of information provided by AUDREY to support decision-making.

Each objective is discussed in further detail below:

Objective 1: Enhanced Integration and Transmission of Data: The application of AI to the problem of data integration focuses on the ability of the system to access and incorporate large data sets from multiple sources. In the case of AHE, these sources included: computer-aided dispatch (CAD) records; standing orders for medical treatments, indications and contraindications (I&C); patient vital sign data; pharmaceutical repositories; threat and hazard guidance; road status and route data; vehicle geolocation data; paramedic voice files; and image files. A paramedic may not have the time or means to access many of these data sources during the course of the call for service. The ability to integrate large volumes of data into operational support hints at a future where paramedics are empowered by data and information that will help them complete their call for service more safely, efficiently and effectively.

Objective 2: Augmented Recognition of Operationally-Relevant Data: Data and information provided to responders must be timely and pertinent to the mission. As more data sources are available, there are concerns about information overload. For example, the *Advanced Life Support Patient Care Standards* used by paramedics in Ontario, Canada, contains 80 medical directives.[17] The applicability of each directive depends on the medical concern, level of paramedic qualifications, the level of consultation with the base hospital physician and pre-authorizations based on specific situations. However, there may be only 2-3 medical directives

[17] Emergency Health Regulatory and Accountability Branch, Ministry of Health and Long Term Care, "Advanced Life Support Patient Care Standards," Version 4.5. In effect May 1, 2018.

that apply to any individual call for service. Paramedics are usually able to recall information from the directives for routine calls based on their training and experience. The ability for an AI system to provide relevant directives for paramedic review, especially for infrequent medical conditions, could provide valuable support to paramedic operations. The application of AI for this problem focuses on the ability of the system to identify those pieces of data or information that are relevant to the call to identify the appropriate directives. Using AI to filter and curate pertinent information for paramedics may improve decision-making, while minimizing information overload.

Objective 3: Improved Patient Care Outcomes: Patient safety is of paramount concern for paramedics, response agencies and medical oversight bodies. Activities that influence patient safety include the collection of a complete medical history, evaluation of vital sign data, assessment of the medical problem(s), administration of the correct medical and physical interventions at the accurate time interval, the mitigation of threats and hazards, and safe vehicles and road conditions for transport. There are multiple applications of AI that can improve patient care outcomes. Alerts for missing information or contraindications for pharmaceuticals, for example, can help to prevent the administration of drugs that may be harmful to the patient. Image recognition of vials or packaging can likewise help prevent the administration of the wrong treatment. Errors can occur during calls for service because paramedics may become overwhelmed by the incident, fatigued, distracted, or by accident. The ability to demonstrate improved patient safety may be one of the most impactful applications of AI for paramedic operations.

Objective 4: Increased Availability of Information: When paramedics are en route to and arrive at the scene of a call for service, they currently have limited access to information. Most advanced life support (ALS) and basic life support (BLS) vehicles (ambulances) have a mounted mobile data terminal (MDT). This is generally a ruggedized laptop where paramedics can receive information related to the call and navigation data. However, due to the location of the MDT, lack of integrated data, activity of the call for service, and level of cellular or network connection, it is difficult for paramedics and EMTs to search for or receive additional information during the call. In Ontario, as in many areas, the ambulance mounted phone allows the paramedic to call, or “patch” to the base hospital to receive additional medical guidance. With a smartphone or tablet that is able to collect and deliver relevant data and information, AI could allow paramedics to quickly access pertinent information when it is needed.

Objective 5: Improved Support to Decision-Making: Paramedics must make numerous time-sensitive decisions during each call for service. In one instance, their assessment is recorded as a score for determining patient acuity, and in another they may administer medications. If the incorrect drug or dosage is chosen, it could cause serious harm to the patient if the paramedic is mistaken in their working diagnosis. In this application of AI, the paramedic is provided with information, alerts and tools to enhance their decision-making. The intent of AI is not to replace the paramedic, but to allow them to respond to each call for service more effectively.

Experiment Scenario

For AHE, one common scenario was used to assess how AGI could enhance paramedic operations. The AHE scenario was focused on a paramedic response to a patient complaining of

chest pain. AUDREY was deployed in this generic scenario to assess its impact on decision-making quality and patient outcomes.

AHE Scenario

"Significant rainfall and snowmelt around the Moira River have caused flooding in and around Hastings County and its member municipalities. Call volume for the paramedic services are at peak levels as the tri-services respond to evacuation and rescue calls. Services are further strained because flood waters and debris have blocked roadways in some areas. These conditions are stressing the staffing and resources of the Hastings-Quinte Paramedic Service (HQPS).

Figure 1. Moira River. Map from Natural Resources Canada

A 9-1-1 Dispatch call is received for a male patient age 50 complaining of substernal chest pain and shortness of breath. Paramedic response is based on required capabilities for type of call, traffic routing, symptoms and resources available for assessment and treatment."

Location

The southern region of Hastings County in Ontario, Canada, was the site for AHE. Figure 2 shows where Hastings County lies relative to surrounding areas. The county is north of Lake Ontario and nearly centered between the cities of Ottawa and Toronto. Hastings County is the second largest county in Ontario with a land area of 6,103.48 km^2.

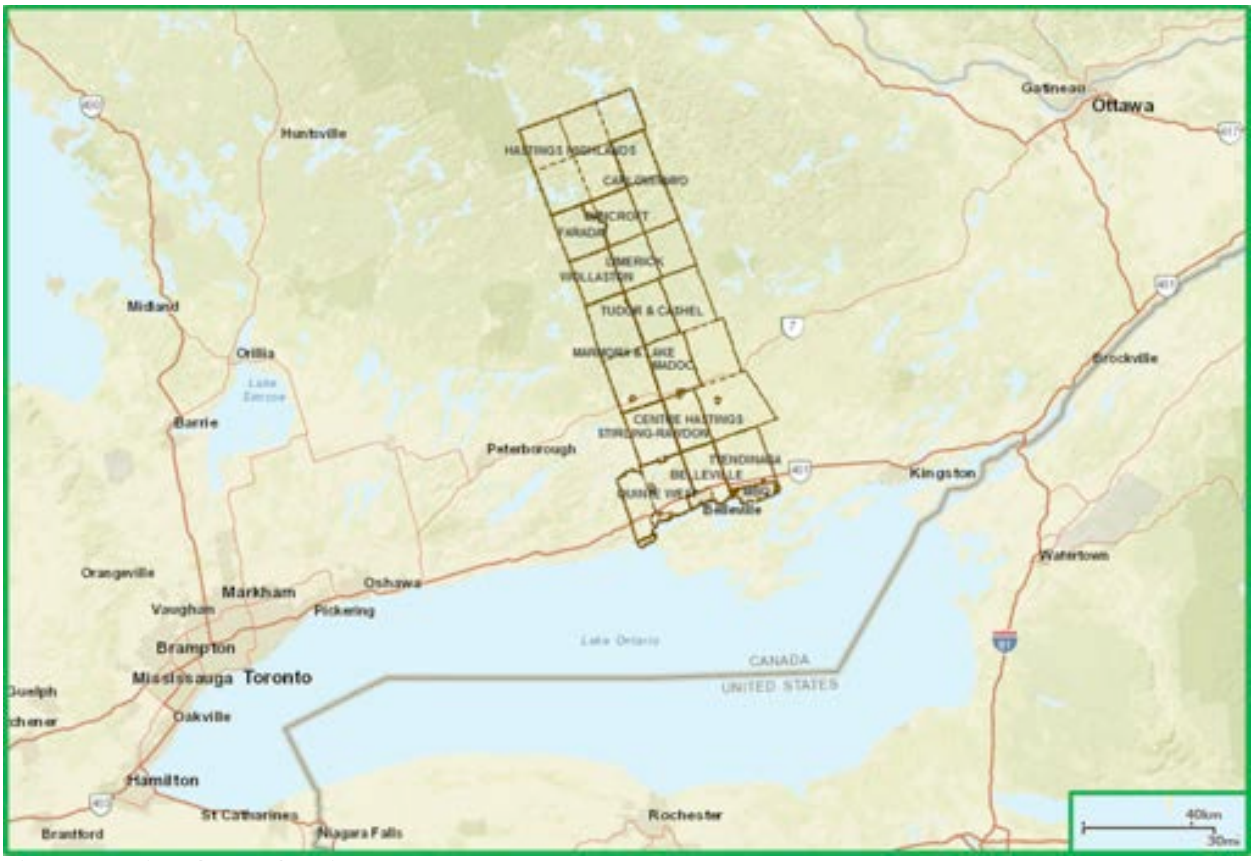


Figure 2. Hastings County, Ontario

Current Capability

In order to assess the benefit provided by AI for responder operations, it is essential to understand current capabilities available to paramedics. An emergency medical call for service begins with a call to a 9-1-1 Public Safety Answering Point (PSAP). Based on the location, this call may be transferred to a separate communication center. In Ontario, medical calls for service are directed to the Central Ambulance Communication Centre (CACC). The dispatcher asks for additional information about the emergency and uses a CAD system to record the details of the call. The dispatcher then determines which unit(s) will be sent to the scene, alerts those units and provides basic call information with the alert. While the unit is en route to the scene, the dispatcher provides addition details. For emergency medical calls, this includes patient age, gender, the chief complaint and any other available information.

When the unit arrives on scene, the paramedics complete an initial size-up of the location to make sure that it is safe for entry. Once they reach the patient, the paramedics perform an evaluation of the patient and collects information and vital signs. The paramedics complete a medical history, asking for additional information about the current condition, past medical history, medications and allergies. Further clinical assessments typically include the patient's pulse, blood pressure and pulse oximetry. The paramedics also conduct a physical exam, take the patient's temperature, and assess his or her level of pain, skin condition and pupil reactivity. A 3-lead electrocardiogram (ECG or EKG) is applied to detect the electrical activity of the heart. Based on the results of the 3-lead ECG, paramedics may attach additional leads to

obtain a 12-lead ECG recording. The paramedics then assess the patient data and develop a treatment plan. Treatments may include physical interventions (e.g., splinting) or medical interventions (e.g., the administration of medication) to address the patient's needs. Medical directives provide standards of practice for treatment of injuries and conditions. For the purposes of AHE, paramedics used the *Advanced Life Support Patient Care Standards, Version 4.5* to guide treatment decisions.

These treatments or procedures are performed on scene and during transport to the medical facility. A paramedic may "patch" (call) a base hospital physician to obtain additional guidance or for permission to extend current treatments beyond what is listed in the medical directive. Upon arrival at the hospital, patient care is transferred to the facility and the paramedic completes the patient record.

Experiment Design

Six use cases were developed for this experiment. Each use case was intended to help assess different capabilities that AUDREY may enhance during a paramedic response. The use cases are described below. Each use case is sectioned into five phases of a typical paramedic call: dispatch, en route, assess, treat, and transport (to hospital).

A two-member crew of HQPS paramedics supported the experiment by fulfilling the roles they ordinarily perform during a medical call throughout all five phases of each use case. The roles of dispatcher, medical command and receiving hospital were simulated. Interdev Technologies' provided historical call data derived from HQPS and RRPEO. The HQPS paramedics used their ambulances and other medical equipment; and the patients and patient data were simulated.

The six use cases designed for the experiment are summarized in the table below:

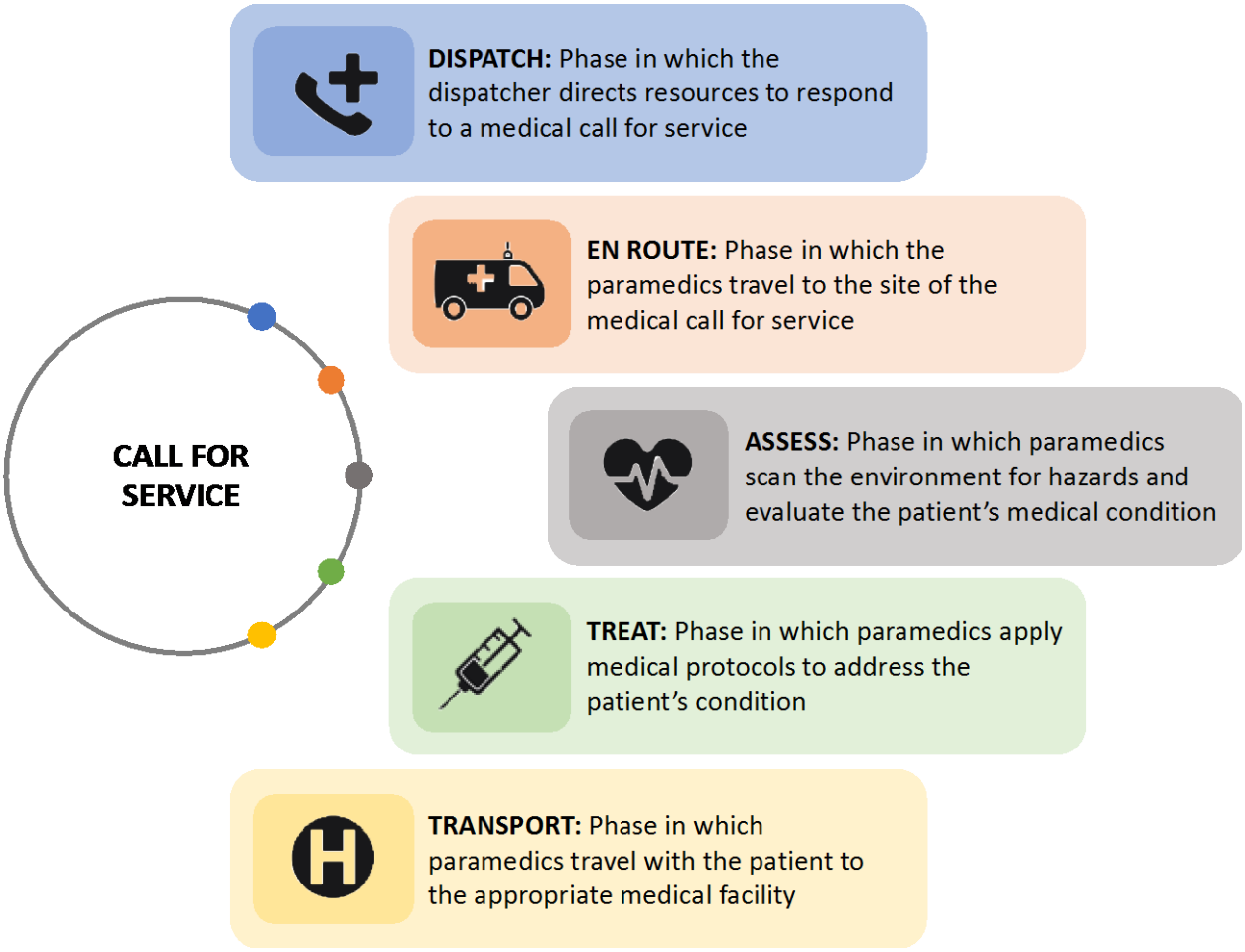
Table 2. AHE Use Cases

Use Case	Description
AHE-1	**Paramedic Service Responds to Call (Baseline):** HQPS responds to a call from a 50-year old male complaining of chest pain. The patient is at an office building in Belleville, ON. Based on patient's signs and symptoms, the paramedics administer nitroglycerine. Because the patient continues to experience chest pain, paramedics contact the physician at a nearby hospital to obtain further medical guidance after the sixth administration of nitroglycerine. This use case did not involve interventions or support from AUDREY. It was intended to set a baseline for other measurements and evaluations.

AHE-2	**AUDREY Supports Paramedic Operations:** HQPS responds to a call from a 50-year old male complaining of chest pain. The patient is at an office building in Belleville, ON. Based on patient's signs and symptoms, paramedics administer nitroglycerine. Because the patient continues to experience chest pain, paramedics contact the physician at a nearby hospital to obtain further medical guidance after the sixth administration of nitroglycerine. This use case mirrors AHE-1, but it includes AUDREY.
AHE-3	**AUDREY Supports Rural Paramedic Operations:** HQPS responds to a call from a 50-year old male complaining of chest pain. The patient is at a single-family residential address in Tweed, ON. Highway 37 near Tweed has been impacted by floodwaters and debris. Road conditions at the time of the call are unknown. AUDREY will support medical assessment and HQPS decision-making in a rural location and will direct HQPS to the appropriate route for transport. In addition, tri-services in Belleville are responding to a multi-building fire caused by a cooking stove. At least 10 patients have been transported to Belleville General Hospital and it is currently on redirect. Flooding effects do not pose a hazard to responders in this use case.
AHE-4	**AUDREY Supports Pediatric Paramedic Operations:** HQPS responds to a call regarding a 13-year old female complaining of chest pain. The patient is at a single-family residential address in Belleville. The caller reports that the patient has a history of drug abuse. AUDREY will support medical assessment and HQPS decision-making when patient assessment differs from standard cardiac patient.
AHE-5	**AUDREY Supports Paramedic Safety during Operations:** HQPS responds to a call from a 50-year old male complaining of chest pain. The patient is at a commercial address on the west side of Belleville, ON, that sells industrial gases and supplies. The business stocks compressed gas cylinders, including flammable and explosive compressed gases. Upon arrival, paramedic hears sounds that may indicate the release of pressurized gas. The paramedic takes photos of visible hazard placard and uploads images. In this use case, AUDREY will support medical assessment and HQPS decision-making, identify on-scene hazards, and provide protective action guidance to paramedics.
AHE-6	**AUDREY Supports Paramedic Operations (Incomplete Information):** HQPS responds to a call from a 50-year old male complaining of chest pain in Belleville, ON. The patient is semi-conscious and unable to provide coherent answers to all questions. The patient's family member is very distraught and hinders the assessment and treatment process. AUDREY will support medical assessment and HQPS decision-making when not all data is available.

As noted above, five phases of an emergency medical call for service were identified to document the AHE results and findings. These phases were used in AHE planning to identify test objectives. Subsequent sections of this report will also categorize outcomes and findings in alignment with these phases. By organizing the AHE results according to the phases, the areas in which AI is most ready to improve the effectiveness, efficiency and safety of operations can be identified.

Figure 3. Phases of Emergency Medical Call for Service



AHE Concept of Operations

Using the five phases of a paramedic call for service, the AHE team identified 109 specific test objectives to assess the efficacy and benefit of AUDREY. In the figures below, the box on the left provides a list of the objectives for each phase. The box on the right (Concept) contains a description of how the team envisioned that AUDREY would support paramedic operations based on those objectives. The Outcomes and Findings section below details the successes and challenges during AHE in meeting these objectives.

Dispatch Phase Objectives

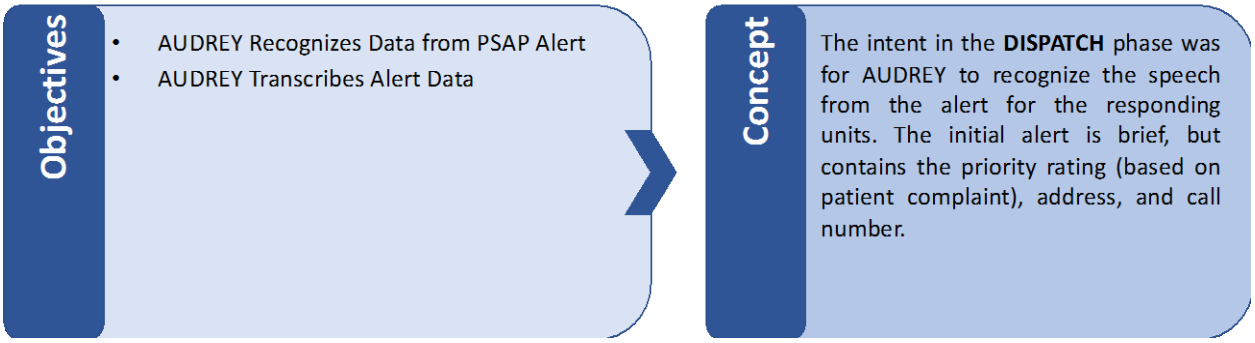


Figure 4. Dispatch Phase Objectives and Concepts

En Route Phase Objectives

Objectives

- AUDREY Recognizes Patient Age
- AUDREY Transcribes Patient Age
- AUDREY Recognizes Patient Gender
- AUDREY Transcribes Patient Gender
- AUDREY Recognizes Patient Symptoms
- AUDREY Transcribes Patient Symptoms
- AUDREY Recognizes Data from Card 1
- AUDREY Transcribes Data from Card 1
- AUDREY Searches Address Call History
- AUDREY Transmits Address Call Data
- AUDREY Searches Patient Health History
- AUDREY Transmits Patient Health Data
- AUDREY Identifies Relevant Standing Orders
- AUDREY Transmits Standing Orders
- AUDREY Accesses Road Status Information
- AUDREY Calculates Route to Call Address

Concept

The intent in the **EN ROUTE** phase was for AUDREY to recognize the additional information provided by the dispatcher, including patient age, gender, and symptoms. AUDREY would then transcribe the call data into the electronic patient record. Using a data set of over 50,000 call records from Hastings County, AUDREY would search previous calls to that address to provide additional situational awareness to the paramedic crew. Likewise, AUDREY would be able to search patient records to provide previous medical history data to the paramedics.

Card 1 data includes symptom-specific information asked by the call-taker. AUDREY would use the call data to identify the correct medical directive and associated standing orders for the call. AUDREY would transmit the standing order to the crew so they can review it while on route to the call address.

In addition, AUDREY would access data from available traffic cameras and navigation systems to identify the safest and most efficient route to the call address.

Figure 5. En Route Phase Objectives and Concepts

Assess Phase Objectives

Objectives

- AUDREY Recognizes Hazard Info
- AUDREY Ingests Images
- AUDREY Recognizes Images
- AUDREY Identifies Relevant Guidance
- AUDREY Transmits Pertinent ERG Guidance
- AUDREY Recognizes Initial CTAS Score
- AUDREY Transcribes Initial CTAS Score
- AUDREY Recognizes Patient History
- AUDREY Records Patient History
- AUDREY Records Metadata: Patient History
- AUDREY Populates Form: Patient History
- AUDREY Recognizes Past Medical History
- AUDREY Records Past Medical History
- AUDREY Records Metadata: Past Medical History
- AUDREY Populates Form: Past Medical History
- AUDREY Recognizes Medications
- AUDREY Records Medications
- AUDREY Records Metadata: Medications
- AUDREY Populates Form: Medications
- AUDREY Recognizes Allergies
- AUDREY Records Allergies
- AUDREY Records Metadata: Allergies
- AUDREY Populates Form: Allergies
- AUDREY Recognizes Physical Findings
- AUDREY Records Physical Findings
- AUDREY Records Metadata: Physical Findings
- AUDREY Populates Form: Physical Findings
- AUDREY Recognizes Patient Pulse Data
- AUDREY Recognizes Patient Blood Pressure Data
- AUDREY Recognizes Patient Pulse Oximetry Data
- AUDREY Recognizes Patient Blood Sugar Data
- AUDREY Recognizes Patient Temperature Data
- AUDREY Recognizes Patient Pupil Data
- AUDREY Recognizes Patient Skin Condition Data
- AUDREY Records Vitals
- AUDREY Records Metadata: Vitals
- AUDREY Populates Form: Vital Measurements
- AUDREY Recognizes Metadata: ECG 3-Lead
- AUDREY Records Metadata: ECG 3-Lead
- AUDREY Recognizes Metadata: ECG 12-Lead
- AUDREY Records Metadata: EKG 12-Lead

Concept

As noted above, the first thing that the paramedic crew does when they arrive at the call address is to perform an assessment of the scene and identify any potential hazards that may cause a safety concern for themselves or their patient. The intent in the **ASSESS** phase was for AUDREY to recognize any hazard information provided by the paramedics, ingest images sent by the crew from the scene, and search a hazard information repository for relevant guidance. AUDREY would then transmit that guidance to the crew.

Once on scene and with the patient, the paramedics begin to assess the patient condition and his or her medical needs. Most of the objectives in this phase include AUDREY recognizing the call-specific data being articulated by the paramedics and integrating data from other sources (i.e., defibrillator). AUDREY would record each piece of data, as well as the time it was recognized, and transcribe the data into the patient medical record.

Figure 6. Assess Phase Objectives and Concepts

Treat Phase Objectives

Objectives

- AUDREY Assesses Completeness of Data
- AUDREY Prompts Paramedic for Missing Data
- AUDREY Recognizes Pertinent Standing Order(s)
- AUDREY Identifies Relevant Guidance
- AUDREY Recognizes Paramedic STEMI Assessment
- AUDREY Records Paramedic STEMI Assessment
- AUDREY Records Metadata: STEMI Assessment
- AUDREY Recognizes Indications & Contraindications (I&C)
- AUDREY Assesses Patient Data for I&C
- AUDREY Prompts Paramedic for I&C
- AUDREY Recognizes Paramedic Plan
- AUDREY Confirms Paramedic Plan
- AUDREY Confirms "Right Patient"
- AUDREY Confirms "Right Drug"
- AUDREY Recognizes Image
- AUDREY Confirms Medication
- AUDREY Confirms "Right Dose"
- AUDREY Confirms "Right Route"
- AUDREY Confirms "Right Time"
- AUDREY Records Medications Administered
- AUDREY Records Metadata: Medications Administered
- AUDREY Provides Medication Reminders
- AUDREY Records Physical Interventions
- AUDREY Records Metadata: Physical Interventions
- AUDREY Transmits Patient Data to Physician
- AUDREY Records Physician Orders
- AUDREY Recognizes Physician Orders
- AUDREY Communicates Physician Orders
- AUDREY Recognizes Second CTAS Score
- AUDREY Records Second CTAS Score
- AUDREY Recognizes Paramedic Baseline Data
- AUDREY Recognizes VitalTag (VT) ECG Data
- AUDREY Recognizes VT Heart Rate Data
- AUDREY Recognizes VT Paramedic Skin Temperature
- AUDREY Recognizes VT Ambient Temp
- AUDREY Recognizes VT Respiratory Rate
- AUDREY Recognizes VT Blood Oxygen Saturation
- AUDREY Recognizes VT Systolic Blood Pressure
- AUDREY Recognizes VT Atmospheric Pressure
- AUDREY Records VT Data
- AUDREY Assesses Paramedic Physiological Data
- AUDREY Alerts Based on Physiological Measurements

Concept

Once the paramedic has gathered all data, he or she will develop a plan for the patient. The intent in the **TREAT** phase was for AUDREY to support this decision-making process. Because AUDREY would have recognized and recorded all of the patient data provided by the paramedic and diagnostic devices, AUDREY would be able to identify whether any data is missing, which may be critical in developing a treatment plan. If a patient has a drug allergy, and the paramedic has forgotten to ask about allergies, the paramedic may administer a medication that could cause a significant reaction. Likewise, because AUDREY was trained on the data in the Patient Care Standards, the system should be able to identify if there are any contraindications that would affect the paramedic plan. Once the plan is developed by the paramedic, AUDREY would then be able to confirm the details to ensure that the medications are given correctly. This includes recognizing images of medications transmitted by the paramedic from the field.

AUDREY would also record when medications were administered and provide reminders for subsequent dosing. When requested by the paramedic, AUDREY would create a patch form using the patient data and transmit that form electronically to the base hospital physician. The physician would provide additional guidance using the form and transmit that back to the paramedics via AUDREY.

It was originally envisioned that AUDREY would measure paramedic physiological signs from a VitalTag sensor and alert if the paramedic was experiencing medical distress.

Figure 7. Treat Phase Objectives and Concepts

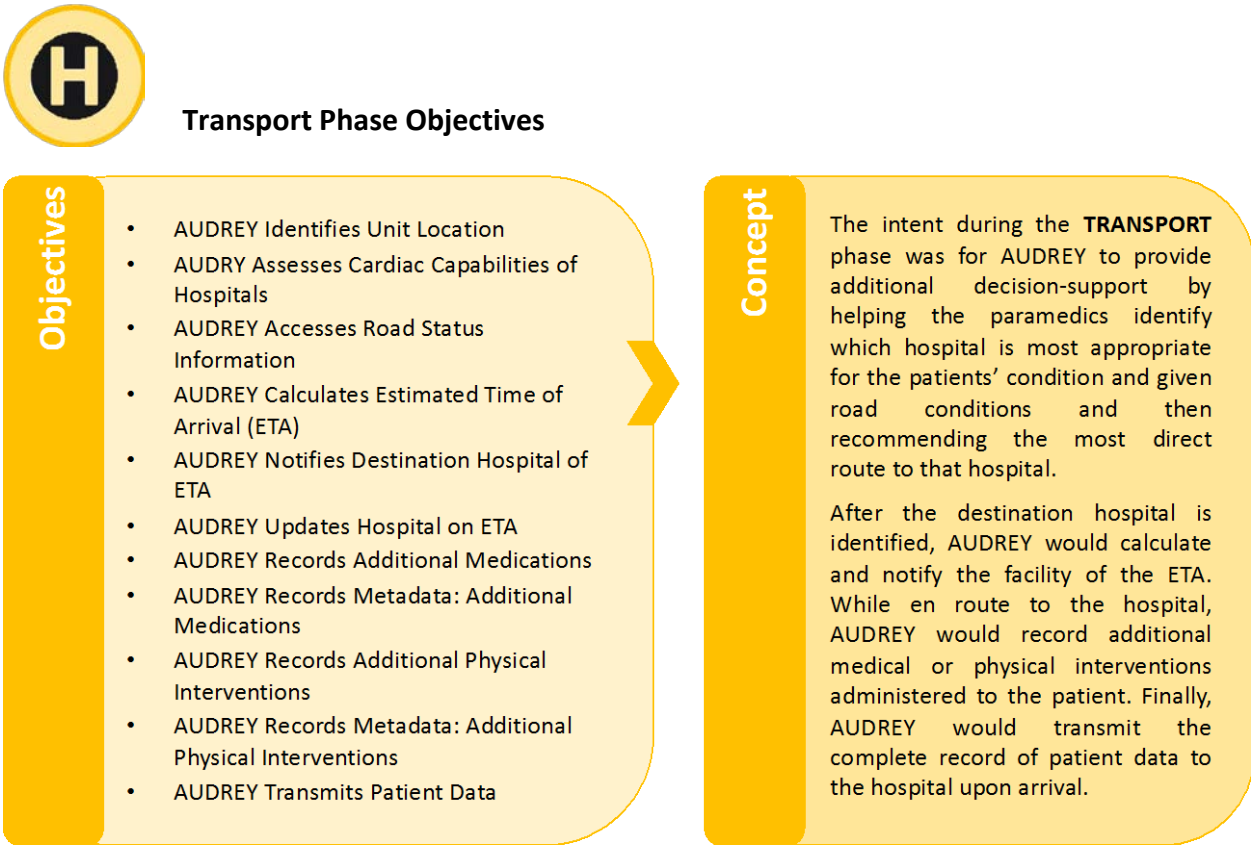


Figure 8. Transport Phase Objectives and Concepts

The project team created multiple artifacts to document the correlation between the experiment objectives and the use cases. Appendix A provides a list of all objectives by phase and tables that illustrate which objectives were intended to be addressed in each use case.

Technology

AUDREY

AUDREY contains a domain-independent reasoning system capable of simultaneously performing inference and learning in real time. AUDREY can retrieve crucial data from disparate sources, employ analytics to extract relevant information, and apply "human-like reasoning" to synthesize and deliver essential insight to first responders. In effect, AUDREY can perform the role of an autonomous assistant serving individuals and groups tasked with incident response.[18]

The paramedic interface with AUDREY was an Android-based Sonim Phone. Referred to as WAMS, the Wireless Alert Messaging System was designed to enable on-demand updates to core functionality. It allowed AUDREY to download IoT sensor processing software to the AUDREY Controller based on the discovered sensors. WAMS can manage communication priorities based on type of traffic (e.g., vital signs can take priority over video when bandwidth

[18] ibid

is limited) and enabled AUDREY to perform limited vital functions when communication is not available.

JPL was given access to two years of historic medical call records for training purposes, as well as for data mining and analysis, to allow it to provide appropriate information during the experiment. All patient health-related data were scrubbed of personally identifiable information to mitigate risks associated with sharing private health information. JPL was also supplied image libraries with photographs of medication labels and hazards labels in preparation for the experiment. A set of three medical directives was provided to JPL, so that AUDREY would have a database to draw upon to select and rank by confidence level the most likely relevant standing orders during the experiment.

Throughout the experiment, AUDREY was required to process voice, image and other data in the scenario to provide paramedics with operationally-relevant information and decision support. AUDREY also was tasked to compile information into medical records and reports.

VitalTag

VitalTag is a lightweight, disposable solution for monitoring trauma patients developed by PNNL. VitalTag monitors numerous vital signs in real-time and broadcasts this data via Message Queuing Telemetry Transport (MQTT) to the desired endpoint. For use cases five and six, VitalTag was intended to take the place of the Zoll defibrillator, which is currently used by HQPS to monitor patient vital signs. VitalTag transmitted simulated data streams for paramedics and AUDREY to use for patient assessment and records.

Integration with Legacy Systems

Throughout this experiment, AUDREY integrated with systems that HQPS uses for their current response operations. These systems and the data integration approach is described in this section. A schematic summary of this is provided in Figure 11.

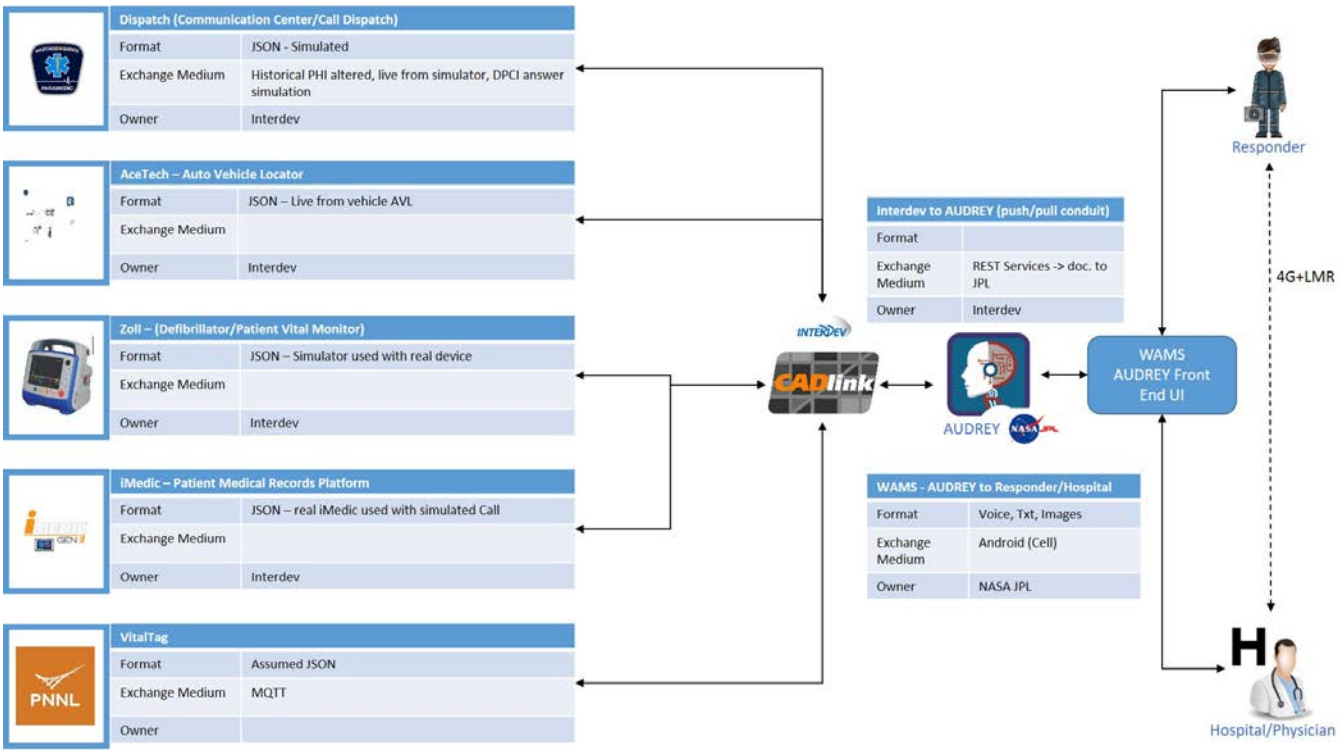


Figure 9. Architecture of Data Sources and Flow for AHE

Interdev supported AHE by using their capabilities to fulfill the typical dispatch system role. An Interdev product, iMedic GEN II, is currently used to capture and share information associated with EMS calls. Electronic patient care records are generated through this software package.

A Zoll® portable defibrillator is used by HQPS paramedics and was a source of data that AUDREY ingested during the scenario. It combines defibrillation and external pacing with electrocardiogram, heart rate, pulse oximetry, non-invasive blood pressure, carbon dioxide concentration, temperature, respiration rate and additional monitoring capabilities. A simulator was used to provide data from a defibrillator for the experiment.

The Hastings County CACC receives details on the nature and location of the incident. The information is entered and recorded in its CAD system. The dispatcher relays information to the paramedic crew through audible alerts and land mobile radios. Access to historical records was scrubbed of personally identifiable information.

Experiment Methodology & Summary

Initial planning for AHE began in late 2017 during a meeting between DRDC CSS and DHS S&T. A site visit to Hastings County in April 2018 gave participants an opportunity to discuss proposed objectives and methodology for the experiment. During the initial site visit, HQPS staff and JPL technologists were able to review the current processes for paramedic calls and identify where AGI may augment capabilities.

Master Scenario Events List (MSEL)

A Master Scenario Events List (MSEL) was developed and used to define the step-by-step activities that took place during AHE. The MSEL was used to validate that AHE scenarios aligned with real-life paramedic operations and to assess AUDREY outcomes during AHE.

Test & Evaluation (T&E) Plan

Throughout the experiment, AUDREY was required to process voice, image and other data in the scenario to provide paramedics with information and decision support. AUDREY also needed to compile information into medical reports (i.e., patch form, Ambulance Call Reports). There were 14 test measures derived for evaluation of AUDREY during AHE. The test and objectives matrix included in Appendix B provides additional detail regarding these test measures and indicates how AUDREY was evaluated based on these test measures.

Table 3. AHE Test Parameters

Test Parameter	Test Measurement	Description
Transmission	Success	AUDREY completes the sharing of each data element x times out of y occurrences per use case
Transmission	Time	Time from initiation of transmission until information reaches end user for each data element and instance in a use case
Recognition	Accuracy	AUDREY populates database for x times out of y occurrences per use case
Recording	Success	AUDREY populates database for x times out of y occurrences per use case
Transcription	Accuracy	AUDREY provides correct data x times out of y times field is populated
Search	Accuracy	AUDREY correctly provides record x times out of y cases when it exists; confirm no false positives (provide record when none exist)
Identification	Accuracy	AUDREY reports correct information for each data element x times out of y occurrences for each data element in the use case
Assessment	Accuracy	AUDREY performs correct assessment of data element in x times out of y expected occurrences in the use case
Prompt	Accuracy	AUDREY confirms the data elements x times out of y expected occurrences per use case
Confirmation	Accuracy	AUDREY confirms the data elements x times out of y expected occurrences per use case
Calculation	Accuracy	AUDREY provides correct data x times out of y times field

		is populated
Audio	Clarity	User feedback on whether the message was understandable or unclear for each occurrence when AUDREY is to communicate to user; Request explanations for failures
Visual	Clarity	User feedback on whether the information was readable or unclear for each occurrence; Request explanations for failures
AV Ingestion	Success	Images are captured by AUDREY in the use case x times out of y attempts for each data element

Dry Run Events

Participants attended a Dry Run event from April 2-4, 2019, where JPL technologists led paramedics from HQPS through the use cases. During the event, participants identified a number of issues that hindered the ability of AUDREY to provide augmented capabilities for medical calls. These issues included the ability of AUDREY to recognize paramedic voices, transcription errors, frequent stopping and starting of WAMS, network connectivity, frequent notification of listening status, delays in image identification, stale data appearing in the patient record and patch form, and software conflicts.

A second assessment was held April 30 through May 2, 2019. During this event, JPL technologists focused on testing specific AUDREY capabilities instead of a systematic assessment of each use case. During the second event, it was identified that AUDREY was not yet capable of accessing road cameras, performing route calculations, choosing among standing orders or identifying contraindications. Further, AUDREY continued to have difficulties with recognizing the voices of some paramedics and recognizing speech regarding patient data.

Based on the outcomes of the Dry Run, a revised set of objectives was agreed upon, with the original set characterized as:

- Current Objectives - to be tested during AHE.
- Partial Objectives - to be tested during AHE, but not in the format or to the extent originally described.
- Amended Objectives - to be tested during AHE, but slight change to objective to make it valid.
- Rescinded Objectives - not to be tested during AHE because the objective is no longer valid or needed.
- Deferred Objectives - not to be tested during AHE because AUDREY has not been trained.

AUDREY Hastings Experiment

The experiment was originally planned for April 23-25, 2019; however, the date was postponed for several months due to the need for continued development of AUDREY capabilities. AHE

was conducted in Belleville, ON (Hastings County), from June 25-27, 2019. The AHE agenda is provided in table 3 below.

Table 4. AHE Agenda

Tuesday, June 25, 2019		
8:30 a.m.	Plenary Meeting	All
9:00 a.m.	Tech Set-Up	JPL, InterDev, PNNL
10:00 p.m.	Training	All
11:00 a.m.	Use Case 1	All
11:30 a.m.	Use Case 1 Debrief	All
12:00 p.m.	Lunch	
1:30 p.m.	Use Case 2	All
2:30 p.m.	Use Case 2 Debrief	All
3:00 p.m.	Use Case 4	All
4:00 p.m.	Use Case 4 Debrief	All
4:30 p.m.	Day 1 Hot Wash	All
5:30 p.m.	Break	
Wednesday, June 26, 2019		
8:30 a.m.	Plenary Meeting	All
9:00 a.m.	Use Case 3	All
10:30 a.m.	Use Case 3 Debrief	All
11:00 a.m.	Use Case 5	All
12:00 p.m.	Use Case 5 Debrief	All
12:30 p.m.	Lunch	
1:30 p.m.	Use Case 6	All
2:30 p.m.	Use Case 6 Debrief	All
3:00 p.m.	Use Case Retrials	All
4:30 p.m.	Day 2 Hot Wash	All
5:30 p.m.	Break	
Thursday, June 27, 2019		
9:00 a.m.	Council Meeting	DHS & JPL Rep
12:00 p.m.	Tech Demo/VIP Event	All
2:00 p.m.	AHE Hot Wash	All
4:00 p.m.	Break	

JPL prepared a training document that was presented to the HQPS paramedics on the morning of Day 1. Although the paramedics had been involved in the Dry Run events and were familiar with AUDREY, the training document conveyed updates to the system and served as a reminder of AUDREY's functionality.

A Hastings County Council Meeting was scheduled for June 27, 2019. The planning of the experiment on that day allowed representatives from Hastings County to receive a briefing from Denis Gusty, the DHS S&T Project Manager, Jay Braun from NASA JPL, and Doug Socha, the HQPS Paramedic Chief on the experiment. Following the meeting, Council members received a technology demonstration of AUDREY capabilities.

Hot Wash Summary

On June 27, 2019, an after-action conference (aka "hot wash") was facilitated for the purpose of debriefing participants and stakeholders. The facilitator asked responders, technologists, evaluators and program staff to reflect on and discuss the outcomes of the experiment. The conference was set up in a "hot wash" format with the primary goals of reviewing how the technologies were used during the experiment, identifying and addressing any issues, and identifying recommendations.

Outcomes and Findings

The assessments below are derived from direct observation of the use cases by NUSTL, DHS Human Systems Integration (HSI), and project staff; AUDREY and CADLink data records; and hot wash results. This section is divided into three parts:

- The first part provides an overview of the use case outcomes;
- The second part provides an assessment of outcomes by phase of an emergency medical call for service; and
- The third part provides findings that reflect the AHE outcomes in a more holistic manner.

Use Case Outcomes

Use Case 1: The purpose of Use Case 1 was to set a baseline for the subsequent use cases. In a typical emergency medical call for service, paramedics collect data during the patient interactions. They must then make note of or remember this data for later inclusion in the patient record. Hours may elapse between when paramedics collect patient data and when it can be entered in the system. Paramedics reported that sometimes they need to "wrack your brain" to remember the details and that they sometimes forget data because of a delay in when they can complete the form. By completing Use Case 1 without AUDREY, evaluators were able to make note of existing processes and durations. Participants estimated that completion of the patient record could take in excess of 30 minutes based on the activities during Use Case 1. The Use Case 1 overview is provided in table 5.

Table 5. Use Case 1 Overview

AHE-1
Title: Paramedic Service (PS) Responds to Call - Baseline
Dispatch Alert/Trigger: "O Base Priority 4, 235 Pinnacle St. Belleville cross streets of Church and Victoria for a male patient complaining of substernal chest pain."
Description: This use case will not involve interventions or support from AUDREY. It is intended to set a baseline for other measurements and evaluations. HQPS will respond to a call from a 50-year old male complaining of chest pain. The patient is at an office building in Belleville, ON. Paramedics administer nitroglycerine based on patient signs and symptoms. Because the patient continues to experience chest pain, paramedics contact the physician to obtain further medical guidance after the sixth administration of nitroglycerine.
Actors: • Hastings-Quinte Paramedic Service (HQPS) (2) • Patient (1) • Dispatch • Physician • Hospital

Primary variable: None

Parameters:

- ☒ Urban
- ☐ Rural
- ☒ Standard patient
- ☐ Alternate patient
- ☐ Residential – Single
- ☐ Residential – Multi
- ☒ Commercial
- ☒ Good connectivity
- ☐ Poor connectivity
- ☒ No hazard present
- ☐ Hazard present

Preconditions:

- HQPS must be able to communicate with ambulance dispatch.
- HQPS must be able to communicate with the physician.
- HQPS must be able to communicate with medical center.

Success Scenario:

- HQPS receives call data from dispatch.
- Upon arrival, paramedics assess patient condition, provide medical treatments and receive guidance from physician.
- HQPS transports patient to Belleville General Hospital.

Original AUDREY Objectives:

None							

Use Case 2: Use Case 2 was intended to be a repeat of Use Case 1, but with the inclusion of AUDREY capabilities. This was used as the initial case for AUDREY to support paramedic decision-making and address many of the objectives.

During Use Case 2, AUDREY:

- Received 12 records that show data received from Dispatch as a source (provided by CADLink) with 55 distinct pieces of information;
- Transmitted one confidence measurement for standing orders to the WAMS unit; however, the orders did not appear on the MDT in the ambulance;
- Accurately received 54 of 56 data files from the defibrillator unit, 52 of those within one second of transmission; however, two data sets were not recorded by AUDREY and two had a long delay in recording;
- Recognized and recorded vital signs from the paramedic, with most values consistent with the scenario;
- Recorded time-related metadata for vital signs "from Medic" consistent with data for one of three records;
- Reported administration of nitroglycerine six times; however, only three doses were observed;
- Provided medication reminders to paramedic around 15:58 and 16:04 and then repeatedly for the next minute; participants explained that the constant reminders were a distraction to their routing operations;
- Generated a patch form and notified the paramedic of missing data (although that data had been provided by the paramedic but not captured by AUDREY);
- Transmitted patch forms to the base hospital physician and destination hospital; and
- Accessed and recognized images of medications from the scene, resulting in "right drug" confirmation within four minutes.

Challenges identified during Use Case 2 included:

- Distraction for the paramedic as AUDREY announced connectivity and status;
- Inconsistent recognition of paramedic speech;
- Erroneous recording of vital signs (e.g., a systolic blood pressure reading of 1700 was listed in the AUDREY records);
- Repeated reports of medication administration due to lack of acknowledgement from AUDREY;
- Inaccurate data in the electronic patient record and patch form;
- Inaccurate timestamping of use case activities;
- Loss of network connectivity for unknown reasons, resulting in the inability of the WAMS device to communicate with the AUDREY backend;
- Existence of stale data in the patient record that did not correspond with the Use Case 2 details (e.g., allergy information);
- Lack of records of the collection, transmission, analysis or reporting of images; and
- AUDREY pulled background noise into the patient record.

Despite issues with omitted data during this use case, the ability of an artificial intelligence system to recognize medical terminology and autofill patient records and patch forms could represent a significant time savings for paramedics. This capability would allow them to spend more time on patient care and less on paperwork, with fewer errors in the patient record.

At one point during the Use Case, the paramedic placed the WAMS device on the patient stretcher and then was unable to find it. This highlighted the need (which was reiterated by the paramedics during the hot wash) for an alternate form factor and user interface for this type of system. Paramedics often need to use two hands as part of their patient examination and treatment. For example, it is not possible to insert an intravenous (IV) line with only one hand. As such, it is not possible to hold a phone or tablet and complete their tasks. The participating paramedics suggested that future form factors may need to attach to their body, garments or equipment and include a microphone that minimizes ambient noises.

The Use Case 2 overview is provided in table 6. The final section of the table (AUDREY Objectives) contains the alphanumerical designation for each objective included in that use case. Dark shading indicates primary objectives and light shading indicates a repeat or secondary objective. Objectives deferred as a result of the Dry Run activities are crossed-out to indicate that they were not evaluated during AHE.

Table 6. Use Case 2 Overview

AHE-2
Title: AUDREY Supports PS Operations
Dispatch Alert/Trigger: "O Base Priority 4, 235 Pinnacle St. Belleville cross streets of Church and Victoria for a male patient complaining of substernal chest pain."
Description: HQPS will respond to a call from a 50-year old male complaining of chest pain. The patient is at a single-family residential address in Belleville, ON. Paramedics administer nitroglycerine based on patient signs and symptoms. Because the patient continues to experience chest pain, paramedics contact the physician to obtain further medical guidance after the sixth administration of nitroglycerine. AUDREY will support medical assessment and HQPS decision-making. This use case mirrors that of AHE-1, but includes AUDREY.
Actors: • HQPS (2) • AUDREY • Patient (1) • Dispatch • Physician • Hospital
Primary variable: With AUDREY

Parameters:

☒ Urban	☒ Standard patient	☒ Residential – Single	☒ Good connectivity
☐ Rural	☐ Alternate patient	☐ Residential – Multi	☐ Poor connectivity
		☐ Commercial	
	☒ No hazard present		
	☐ Hazard present		

Preconditions:

- HQPS must be able to communicate with ambulance dispatch.
- AUDREY must be able to communicate with HQPS paramedics in ambulance.
- AUDREY must be able to communicate with ambulance dispatch.
- AUDREY must be able to communicate with the physician.
- HQPS must be able to communicate with hospital.
- AUDREY must be able to access real-time location of ambulance.
- AUDREY must be able to communicate with hospital.

Success Scenario:

- HQPS receives call data from ambulance dispatch.
- Upon arrival, paramedics assess patient condition and provide medical treatments. HQPS transports patient to hospital.
- AUDREY supports HQPS operations and decision-making. AUDREY augments communications between HQPS and physician and between HQPS and hospital.

Original AUDREY Objectives:							
D1	E10	A12	A23	A33	T3	T18	T29
D2	~~E11~~	A13	A24	A34	T7	T19	
E1	~~E12~~	A14	A25	A35	T8	T20	~~H1~~
E2	E13	A15	A25	A36	~~T10~~	T21	~~H3~~
E3	E14	A16	A26	A37	~~T11~~	T22	~~H4~~
E4	A6	A17	A27	A38	T12	T23	~~H5~~
E5	A7	A18	A28	A39	T13	T24	~~H6~~
E6	A8	A19	A29	A40	T14	T25	H7
E7	A9	A20	A30	A41	T15	T26	H8
E8	A10	A21	A31	T1	T16	T27	H9
E9	A11	A22	A32	T2	T17	T28	

Use Case 3: Use Case 3 focuses on operations in a rural setting. The town of Tweed, Ontario, has a population of just over 6,000 people. It is approximately a 30-minute drive (39 kilometers) from Belleville and is located near several lakes and waterways that frequently experience flooding. The more-rural location suggests that network connectivity may be more of an issue on calls for service in that area. This use case also incorporates an inject that indicates that the patient is suffering from an ST-Elevated Myocardial Infarction (STEMI), which is a serious type of heart attack that requires specialized care. There are two medical centers to which paramedics responding to a potential STEMI call in Tweed might transport the patient, Kingston General Hospital and Peterborough Regional Health Centre. The intent was for AUDREY to access road condition data (due to potential flooding in the area) to calculate estimated times of arrival (ETAs) to both hospitals and identify which could be reached within the 60-minute window required for a STEMI treatment. Because this was not possible due to the status of AUDREY capabilities, several of the primary objectives associated with this use case were not attempted.

During Use Case 3, AUDREY:

- Received 12 records that show data received from Dispatch as a source (provided by CADLink) with 55 distinct pieces of information;
- Transmitted one confidence measurement for standing orders to the WAMS unit and MDT;
- Accurately received all 55 files sent from the defibrillator unit (transmitted once per minute), with 54 received within one second;
- Recorded 5 sets of vitals “from Medic”: blood pressure (BP), heart rate (HR), oxygen (O2) saturation (Sat), and RR at 10:25 and 10:39; pain level at 10:27 and 10:40; and level of awareness (LOA) at 10:33, with all values being consistent with the scenario;

- Recorded 19 instances where medications were administered, although this exceeds the number of actual doses that were observed or were consistent with the scenario:
    - Nitroglycerine (NTG) at 10:35, 10:36, 10:41, 10:47, 10:57, 11:06, 11:07, 11:08, and 11:09;
    - Morphine at 10:52, 10:58, 11:07, 11:08, 11:09, and 11:10 (twice);
    - Normal saline at 10:58, 11:07, and 11:08; and
- Generated three patch forms at 10:34:50, 10:41:07, and 10:52:17, each with 33 fields of information.

Challenges reported during Use Case 3 include:

- In 12 instances, a given medication was listed as administered more frequently than once every five minutes (10:35-10:36, 11:06-11:10), which indicates that the paramedics may have made multiple attempts to communicate the administration to AUDREY, but were uncertain if it was captured by the system;
- Observations of medications administered not captured by AUDREY;
- Uncertainty on the part of the paramedic on how to communicate the administration of medications to AUDREY;
- Absence of records that document the use of AUDREY to provide medication reminders, although it should have been included (following each such administration);
- Paramedics unsuccessfully requested a patch form at 10:31 with cause unknown;
- Paramedics required assistance from JPL staff on how to incorporate a request for medication approval into the patch form;
- Some language in the patch forms suggests that AUDREY either did not translate the paramedic correctly or incorporated some stray dialog into the records (“night review” in history field and “I mean” in treatment field);
- No records that document the use of AUDREY to provide image analysis in this use case, although it should have been included for the confirmation of the medications (for each such administration);
- An audio AUDREY message from the phone concerning the network connection distracted/interrupted the base hospital physician while trying to use AUDREY;
- Paramedics noted that there was missed data which was transmitted verbally, specifically noting that skin condition, GCS and CTAS were not always captured; and
- Base physicians noted that text entries into WAMS did not stay in the correct field.

The Use Case 3 overview is provided in table 7.

Table 7. Use Case 3 Overview

AHE-3
Title: AUDREY Supports Rural Paramedic Operations
Dispatch Alert/Trigger: "Priority 2, 123 Main St. Tweed"
Description: HQPS will respond to a call from a 50-year old male complaining of chest pain. The patient is at a single-family residential address in Tweed, ON. Highway 37 near Tweed has been impacted by floodwaters and debris. Road conditions at the time of the call are unknown. AUDREY will support medical assessment and HQPS decision-making in a rural location and will direct HQPS to the appropriate route for transport. Tri-services in Belleville are responding to a multi-building fire caused by a cooking stove. At least 10 patients have been transported to Belleville General Hospital and it is currently on redirect. Flooding effects do *not* pose a hazard to responders in this use case.
Actors: • HQPS (2) • AUDREY • Patient (1) • Dispatch • Physician • Hospital
Primary variable: Rural patient location
Parameters: ☐ Urban ☒ Rural ☒ Standard patient ☐ Alternate patient ☒ Residential – Single ☐ Residential – Multi ☐ Commercial ☐ Good connectivity ☒ Poor connectivity ☒ No hazard present ☐ Hazard present
Preconditions: • HQPS must be able to communicate with ambulance dispatch. • AUDREY must be able to communicate with HQPS paramedics in ambulance. • AUDREY must be able to communicate with ambulance dispatch. • AUDREY must be able to communicate with the physician. • HQPS must be able to communicate with hospital. • AUDREY must be able to access real-time location of ambulance. • AUDREY must be able to access real-time traffic and road condition data. • AUDREY must be able to communicate with hospital.

Main Success Scenario:

- HQPS receives call data from dispatch.
- Upon arrival, paramedics assess patient condition and provide medical treatments. HQPS transports patient to hospital.
- AUDREY supports HQPS operations and decision-making.
- AUDREY augments communications between HQPS and physician and between HQPS and hospital.
- AUDREY calculates ETA for appropriate destination hospital.

Original AUDREY Objectives:

D1	~~E11~~	A12	A24	A35	T6	T22	~~H3~~
D2	~~E12~~	A13	A25	A36	T8	T23	~~H4~~
E1	E13	A14	A25	A37	~~T10~~	T24	~~H5~~
E2	E14	A15	A26	A38	~~T11~~	T25	~~H6~~
E3	~~E15~~	A16	A27	A39	T12	T26	H7
E4	~~E16~~	A17	A28	A40	T15	T27	H8
E5	A6	A18	A29	A41	T16	T28	H11
E6	A7	A19	A30	T1	T17	T29	
E7	A8	A20	A31	T2	T18		
E8	A9	A21	A32	T3	T19		
E9	A10	A22	A33	T4	T20	~~H1~~	
E10	A11	A23	A34	T5	T21	~~H2~~	

Use Case 4: Use Case 4 introduced injects that provided contraindications against the administration of physical or medical interventions. The patient was a 13-year old female experiencing chest pain, potentially related to a drug overdose. In such a call for service, paramedics would collect patient data, treat appropriately and transport her directly to the hospital. The intent was to evaluate whether AUDREY would recognize the contraindications for adult standing orders. This use case also did not require AUDREY to confirm the paramedic plan or provide medication reminders.

During Use Case 4, AUDREY:

- Received 12 records that show data received from dispatch as a source (provided by CADLink) with 55 distinct pieces of information;
- Transmitted no standing orders or confidence level (consistent with JPL guidance that AUDREY would not transmit if none were applicable);
- Accurately received all 20 files sent from the defibrillator unit (transmitted once per minute), with 18 received within one second;
- Recorded three sets of vitals "from Medic": LOA, BP, HR and O2 Sat at 16:39 and LOA, O2 Sat, Respirations at 16:52 (however, this timestamp is after the observed end of the call);
- Did not record any instances of the administration of a medication or provide any medication reminders (consistent with the use case injects); and
- Generated one patch form at 16:50 with 33 fields of information.

Challenges reported during Use Case 4 include:

- Absence of standing order or confidence level (without notification that none would be sent or explanation for rationale) may result in paramedics anticipating something that will never arrive;
- Observations showed several unsuccessful attempts around 16:40 to create a patch form;
- Inaccurate timestamping of use case activities (including some reported after the observed conclusion of the use case);
- Stale data (patient name) from the previous use case was included in the patient record;
- AUDREY frequently broadcasted messages regarding its network connection status, such as "connected to Wi-Fi" and information on MQTT;
- Information was already populated by AUDREY in the patient record at the start of the call for Allergies, Medications and Past Medical History for patient, presumed during the use case to be from previous calls at that address; and
- Paramedics were unaware that AUDREY was recording audio at times during the call.

The Use Case 4 overview is provided in table 8.

Table 8. Use Case 4 Overview

AHE-4
Title: AUDREY Supports Pediatric Paramedic Operations

Dispatch Alert/Trigger: "Priority 2, 456 Main St. Belleville, #####"

Description: HQPS will respond to a call regarding a 13-year old female complaining of chest pain. The patient is at a single-family residential address in Belleville. The caller reports that the patient has a history of opiate abuse. AUDREY will support medical assessment and HQPS decision-making when patient assessment differs from standard patient.

Actors:

- HQPS (2)
- AUDREY
- Patient (1)
- Dispatch
- Physician
- Hospital

Primary variable: Pediatric patient

Parameters:

☒ Urban	☐ Standard patient	☒ Residential – Single	☒ Good connectivity
☐ Rural	☒ Alternate patient	☐ Residential – Multi	☐ Poor connectivity
		☐ Commercial	
	☒ No hazard present		
	☐ Hazard present		

Preconditions:

- HQPS must be able to communicate with dispatch.
- AUDREY must be able to communicate with HQPS paramedics in ambulance.
- AUDREY must be able to communicate with dispatch.
- AUDREY must be able to communicate with the physician.
- HQPS must be able to communicate with hospital.
- AUDREY must be able to access real-time location of ambulance.
- AUDREY must be able to communicate with hospital.

Main Success Scenario:

- HQPS receives call data from dispatch.
- Upon arrival, paramedics assess patient condition and provide medical treatments.
- HQPS transports patient to medical center.
- AUDREY supports HQPS operations and decision-making.
- AUDREY augments communications between HQPS and physician and between HQPS and medical center.
- AUDREY successfully identifies appropriate standing orders and medication dosage for pediatric patient.

Original AUDREY Objectives:

D1	E10	A12	A23	A33	T3	T18	T29
D2	~~E11~~	A13	A24	A34	T7	T19	~~H1~~

E1	~~E12~~	A14	A25	A35	T8	T20	~~H3~~
E2	E13	A15	A25	A36	~~T10~~	T21	~~H4~~
E3	E14	A16	A26	A37	~~T11~~	T22	~~H5~~
E4	A6	A17	A27	A38	T12	T23	~~H6~~
E5	A7	A18	A28	A39	T13	T24	H7
E6	A8	A19	A29	A40	T14	T25	H8
E7	A9	A20	A30	A41	T15	T26	H9
E8	A10	A21	A31	T1	T16	T27	H10
E9	A11	A22	A32	T2	T17	T28	H11

Use Case 5: Use Case 5 injects focused on potential hazards to responders on the incident scene and the use of VitalTag to provide patient vital sign information (instead of the Zoll defibrillator). As noted above, it was originally envisioned that the VitalTag sensor would be attached to one of the paramedics, but this objective was amended due to privacy concerns, and logistics around human subjects testing. This use case also included an inject that the patient was using a medication that would constitute a contraindication for the administration of one medication. The intent was to determine whether AUDREY could identify this contraindication to prevent the administration of a potentially dangerous drug to the patient. However, because AUDREY was not trained to identify contraindications from the medical directives, this objective was not evaluated.

Also of note, this use case was cut short for reasons not in the control of HQPS or JPL. The industrial facility, designated as the location for this use case, was hosting an event and was not available to provide a hazard placard, necessary to the use case.

During Use Case 5, AUDREY:

- Transmitted one confidence measurement for standing orders to the MDT;
- Captured an image of a placard on a separate smartphone at 12:00 and the AUDREY record shows that the image resulted in identification of Anhydrous Ammonia within about one minute;
- Accurately received all 23 files sent from the defibrillator unit (transmitted once per minute), with 21 received within one second;
- Received 17 records that show data received from Dispatch as a source (provided by CADLink) with 55 distinct pieces of information; however, the first record was timestamped as having been created before the crew was dispatched and contained data from the previous use case, and the last was timestamped after the call ended and was a duplicate of the previous record;
- Recorded 3 sets of vitals “from Medic” with BP, HR and O2 Sat in one record, pain level in another, and breath sounds the third;
- Did not record any instances of the administration of a medication or provide any medication reminders (consistent with the use case injects); and
- Generated one patch form with 33 fields of information.

Challenges reported during Use Case 5 include:

- Paramedics had difficulty capturing the image of the hazard placard until they moved to the shade (which may not always be possible);
- No observation record exists to show if the identification of the hazard was relayed to the paramedics;
- AUDREY was not trained on the data in the Emergency Response Guidebook (ERG) and was therefore unable to provide any protective action guidance to the paramedics on scene;
- Some language in the patch forms suggests that AUDREY either did not translate the paramedic correctly or incorporated some stray dialog into the records, which suggests there may have been carry over of information from prior use case where new information may have been appended to older data; and
- JPL noted that at times AUDREY was picking up on its own audio and incorporating it into the call data.

The Use Case 5 overview is provided in table 9.

AHE-5
Title: AUDREY Supports Paramedic Safety during Operations
Dispatch Alert/Trigger: "Priority 2, 789 Main St., Belleville"
Description: HQPS will respond to a call from a 50-year old male complaining of chest pain. The patient is at a commercial address on the west side of Belleville, ON, that sells industrial gases and supplies. The business stocks compressed gas cylinders, including flammable and explosive compressed gases. Upon arrival, paramedic hears sounds that may indicate the release of pressurized gas. The paramedic takes photos of visible hazard placard and uploads images. AUDREY will support medical assessment and HQPS decision-making. AUDREY identifies on-scene hazards and provides protective action guidance to paramedics. AUDREY recognizes VitalTag physiological data.

Actors:

- HQPS (2)
- AUDREY
- VitalTag
- Patient (1)
- Dispatch
- Physician
- Hospital

Primary variable: Hazard present

Parameters:

☒ Urban	☒ Standard patient	☐ Residential – Single	☒ Good connectivity
☐ Rural	☐ Alternate patient	☐ Residential – Multi	☐ Poor connectivity
		☒ Commercial	
	☐ No hazard present		
	☒ Hazard present		

Preconditions:

- HQPS must be able to communicate with ambulance dispatch.
- AUDREY must be able to communicate with HQPS paramedics in ambulance.
- AUDREY must be able to receive images from paramedics.
- AUDREY must be able to communicate with VitalTag.
- AUDREY must be able to communicate with dispatch.
- AUDREY must be able to communicate with the physician.
- HQPS must be able to communicate with hospital.
- AUDREY must be able to access real-time location of ambulance.
- AUDREY must be able to communicate with hospital.

Main Success Scenario:

- HQPS receives call data from dispatch.
- Upon arrival, paramedics assess patient condition and provide medical treatments. HQPS transports patient to hospital.
- AUDREY supports HQPS operations and decision-making.
- AUDREY augments communications between HQPS and physician and between HQPS and hospital.
- AUDREY successfully identifies on-scene hazards and provides protective action guidance to paramedics.
- AUDREY interacts with VitalTag.
- AUDREY identifies appropriate standing orders and medication dosage.

AUDREY Objectives:							
D1	~~E12~~	A11	A24	A36	T12	T26	T39
D2	E13	A12	A25	A37	T13	T27	~~T40~~
E1	E14	A13	A25	A38	T14	T28	T41
E2	A1	A14	A26	A39	T15	T29	H1
E3	A2	A15	A27	A40	T16	~~T30~~	H3
E4	A3	A16	A28	A41	T17	T31	H4
E5	A4	A17	A29	T1	T18	T32	H5
E6	A5	A18	A30	T2	T19	T33	H6
E7	A6	A19	A31	T3	T20	~~T34~~	H7
E8	A7	A20	A32	T7	T21	T35	H8
E9	A8	A21	A33	T8	T22	T36	H9
E10	A9	A22	A34	T9	T23	T37	H10
~~E11~~	A10	A23	A35	~~T10~~	T24	~~T38~~	H11
				~~T11~~	T25		

Use Case 6: DHS S&T and DRDC CSS staff agreed that it was unnecessary to complete Use Case 6 because AUDREY was unable to recognize or prompt for the contraindications planned as injects in the use case. The Use Case 6 overview is provided in table 10.

Table 9. Use Case 6 Overview

AHE-6
Title: AUDREY Supports Paramedic Operations – Incomplete Information
Dispatch Alert/Trigger: "Priority 2, 1011 Main St., Apt 1213 Belleville"
Description: HQPS will respond to a call from a 50-year old male complaining of chest pain. The patient is at a multi-family residential address in Belleville, ON. The patient is semi-conscious and unable to provide coherent answers to all questions. The patient's family member is very distraught and hinders the assessment and treatment process. AUDREY will support medical assessment and HQPS decision-making. AUDREY will integrate VitalTag's physiological measurements of the paramedic during the call.

Actors:

- HQPS (2)
- AUDREY
- Patient (1)
- Dispatch
- Physician
- Hospital
- VitalTag

Primary variable: Incomplete patient data

Parameters:

☒ Urban	☒ Standard patient	☐ Residential – Single	☒ Good connectivity
☐ Rural	☐ Alternate patient	☒ Residential – Multi	☐ Poor connectivity
		☐ Commercial	
	☒ No hazard present		
	☐ Hazard present		

Preconditions:

- HQPS must be able to communicate with ambulance dispatch.
- AUDREY must be able to communicate with HQPS paramedics in ambulance.
- AUDREY must be able to communicate with dispatch.
- AUDREY must be able to communicate with the physician.
- AUDREY must be able to communicate with VitalTag.
- HQPS must be able to communicate with hospital.
- AUDREY must be able to access real-time location of ambulance.
- AUDREY must be able to communicate with hospital.

Main Success Scenario:

- HQPS receives call data from dispatch.
- Upon arrival, paramedics assess patient condition and provide medical treatments. HQPS transports patient to hospital.
- AUDREY supports HQPS operations and decision-making.
- AUDREY augments communications between HQPS and physician and between HQPS and hospital.
- AUDREY successfully prompts paramedic regarding missing assessment information and treatment information.
- AUDREY integrates with VitalTag.

Original AUDREY Objectives:

D1	~~E12~~	A16	A28	A41	T16	T29	~~H1~~
D2	E13	A17	A29	T1	T17	~~T30~~	~~H3~~
E1	E14	A18	A30	T2	T18	T31	~~H4~~
E2	A6	A19	A31	T3	T19	T32	~~H5~~

E3	A7	A20	A32	T7	T20	T33	~~H6~~
E4	A8	A21	A33	T8	T21	~~T34~~	H7
E5	A9	A22	A34	T9	T22	T35	H8
E6	A10	A23	A35	~~T10~~	T23	T36	H9
E7	A11	A24	A36	~~T11~~	T24	T37	H10
E8	A12	A25	A37	T12	T25	~~T38~~	H11
E9	A13	A25	A38	T13	T26	T39	
E10	A14	A26	A39	T14	T27	~~T40~~	
~~E11~~	A15	A27	A40	T15	T28	T41	

The following section contains a description of exercise outcomes by incident phase. As noted above, organizing the AHE results according to the phases can help to identify the areas in which AI is most ready to improve the effectiveness, efficiency and safety of operations. In addition, those phases where AI requires further development to meet the test objectives can also be pinpointed.

Dispatch Phase Outcomes

The dispatch phase is relatively short. It includes the notification of units that they have been assigned to a call for service. Information relayed during the initial dispatch alert is not extensive, but it provides initial situational awareness of the call. The priority rating assigned to the call is based on the acuity of the patient's condition. Calls for life-threatening cardiac issues are assigned as "Priority 4."

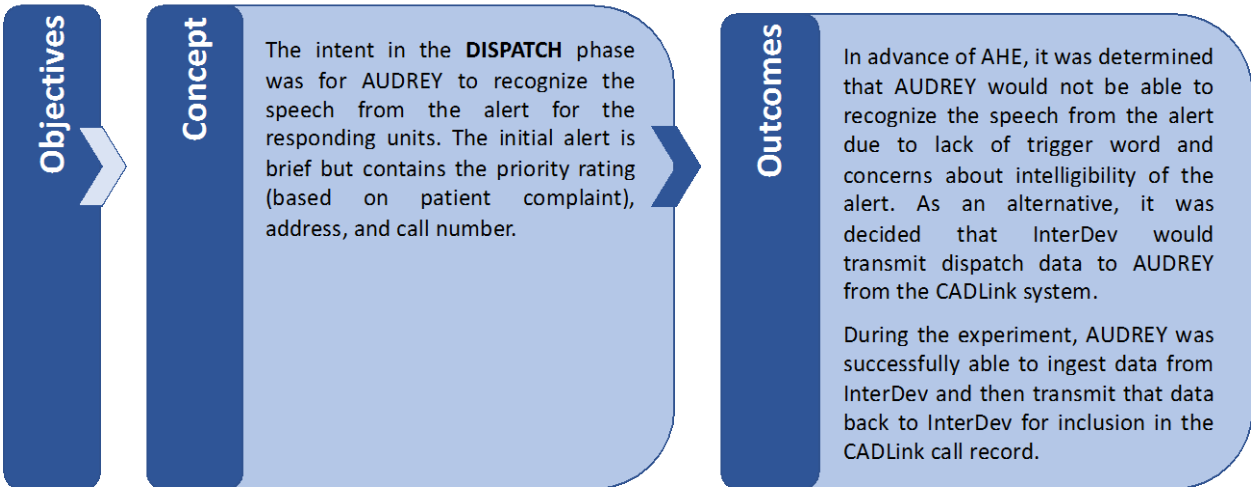


Figure 10. Dispatch Phase Outcomes

En Route Phase Outcomes

While en route, paramedics are provided with limited additional information about the patient, including patient age, gender and initial details about the complaint. There currently are 18 core and 12 auxiliary medical directives for primary care paramedics, and 29 core and 15 auxiliary medical directives for advance care paramedics. While some medical directives are used frequently, there are many that are not. Having the ability to reference less used medical directives prior to arrival at the call could help in preparing medical calculations and scene management planning prior to arriving at the scene. It was envisioned that AUDREY would be able to assess the data from the dispatcher to identify the appropriate standing order and send this reference to the paramedics while en route to the scene, along with a confidence interval of probability. This information was based on the historical call database supplied by HQPS.

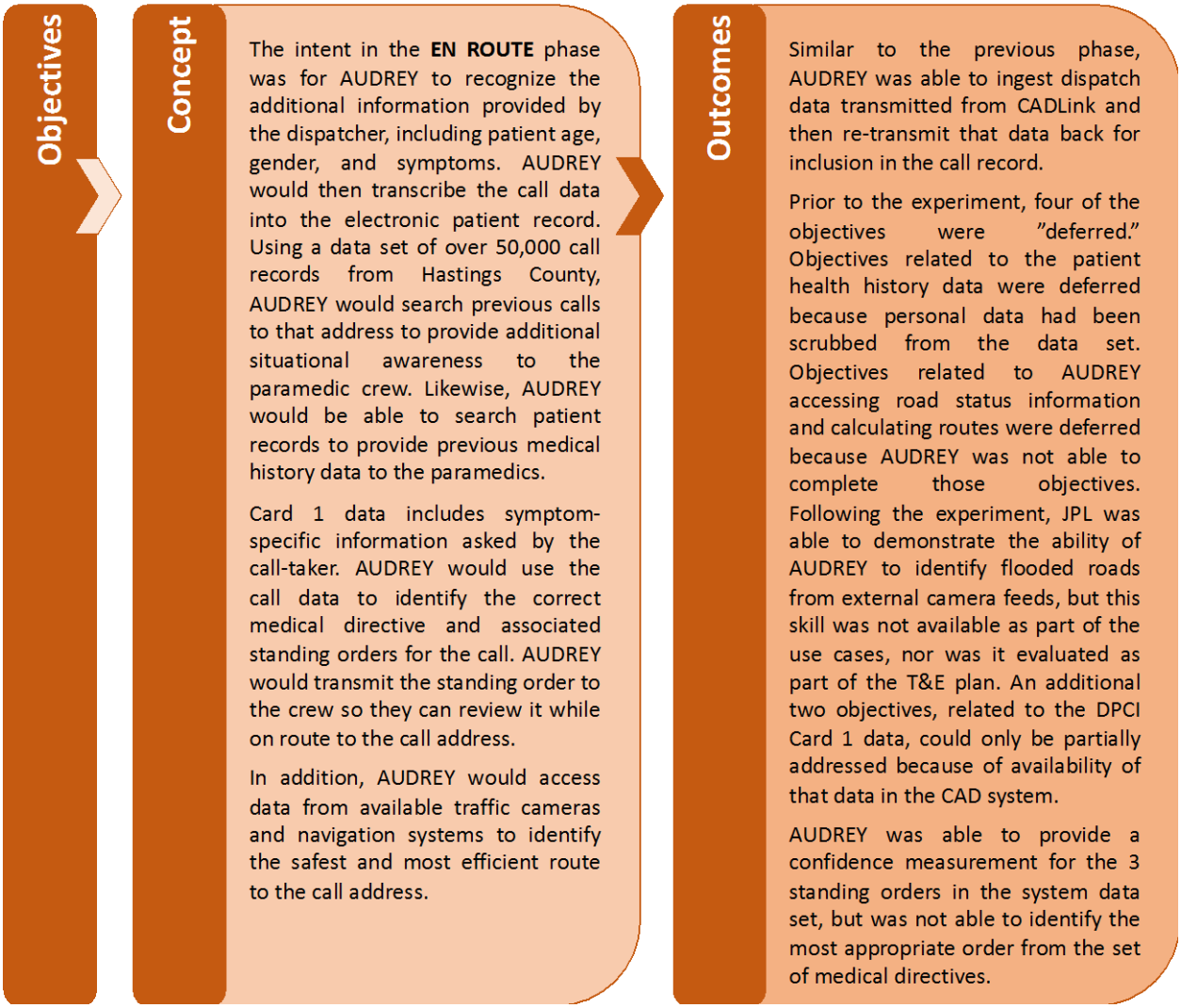


Figure 11. En Route Phase Outcomes

Assess Phase Outcomes

Many of the objectives in the Assess phase involved AUDREY recognizing patient information as it was articulated by the paramedics during each use case. As the paramedic was obtaining information from the patient (e.g., past medical history, allergies), he or she would then repeat the data. There was some confusion about whether an AUDREY wake word was needed (e.g., "Okay, AUDREY"). The paramedic repeating the data is not a current process during an emergency medical call for service. As will be discussed further in the conclusions section, this finding that the adoption of artificial intelligence technology may require some adaptation of responder processes and procedures should be addressed through the development and adoption of new systems.

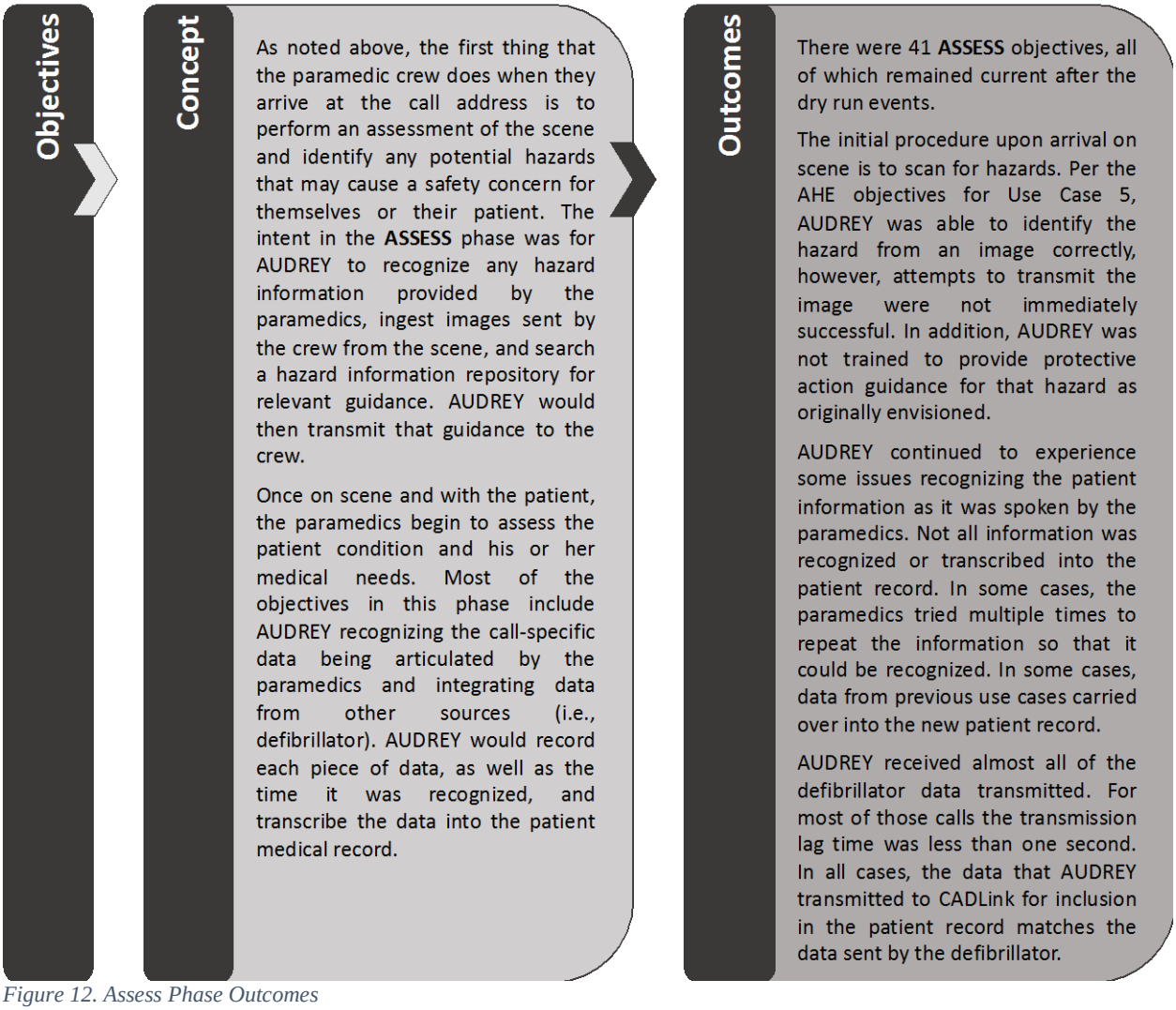


Figure 12. Assess Phase Outcomes

Treat Phase Outcomes

AUDREY realized incremental success in the treatment phases of the use cases. In some cases, AUDREY was able to recognize images and paramedic speech, provide medication reminders, and generate and transmit patch forms. However, AUDREY was never able to perform all of these functions in a contiguous integrated manner, as the definitions for success in each use case would require.

Figure 13. Treat Phase Outcomes

Transport Phase Outcomes

Because of the amendment of the objectives following the Dry Run events, AUDREY introduced no new capabilities in the transport phase. Because AUDREY was not trained on the cardiac capabilities of the available medical facilities and was unable to identify road hazards, the system was not able to support destination or route decision-making. As noted above, JPL did demonstrate the capability for AUDREY to process images to identify water inundation and flooding (outside of the use case scenarios), but this capability was not ready for inclusion in the exercise.

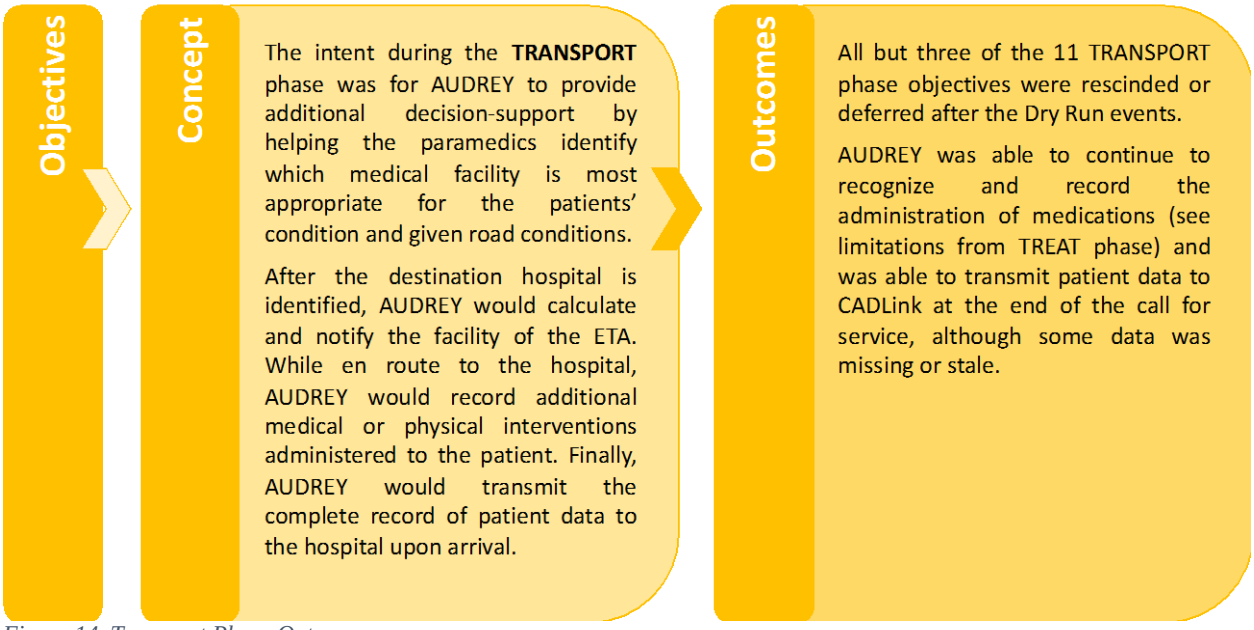


Figure 14. Transport Phase Outcomes

Assessment of AHE Outcomes and Findings

The following section provides analysis of the results of AHE aligned with the strategic objectives of the incident.

Patient Safety Outcomes

Patient safety is a serious global public health concern and is vital in any type of healthcare setting. According to the World Health Organization (WHO), there is a one in 300 chance of a patient being harmed while receiving care.[19] Notably, "unsafe medication practices and medication errors are a leading cause of avoidable harm" in healthcare globally.[20] These errors occur primarily due to weak medication systems and/or human factors. Human factors may include fatigue of personnel, poor working conditions, workflow interruptions or staffing shortages. Essentially, regardless of experience, intelligence, motivation or vigilance, paramedics are human and they do and will make mistakes. In emergency medical situations, providers are operating in a fast-paced environment where decisions must be made quickly, with little information and under less than ideal conditions. Pair this with the human element and it becomes a high-risk setting for a medication error to occur. Paramedics are required not only to have drug dosages and protocol memorized, but are also expected to be able to perform mental calculations for the appropriate patient dose. This requires annual certification. Research has shown that memorization/mental calculation of dosing can actually increase the risk of committing a medication error.[21]

AUDREY aimed to improve patient safety outcomes by significantly reducing medication errors. During AHE, both participating base hospital physicians and paramedics alike expressed that patient safety precautions, confirmation of right medications and reducing human error are critical issues that need to be addressed. Further, they appeared to overwhelmingly agree that AI could eventually help solve many of these issues simply by being able to transmit accurate and timely communications. Medication verification through AUDREY includes use of the WAMS device to take a picture of the medication and send it for analysis, while also vocally stating the name of the medication and dosage the paramedic plans to administer. Once analysis is complete, AUDREY could communicate confirmation or concerns about the treatment plan. During the experiment, there were some inconsistencies with AUDREY's ability to process and transmit such images.

In addition to verifying medications, AUDREY also provides medication reminders for the paramedic. However, AUDREY's ability to do this was also inconsistent. It may also be important to note that all of these capabilities may be significantly reduced if AUDREY cannot connect to Wi-Fi (e.g., responding to a rural area) and also if AUDREY is unable to decipher between relevant and irrelevant information. For instance, AUDREY had retained information about nitroglycerine that was stated in casual paramedic conversation. It understood this information as the paramedic having administered nitroglycerine to the patient, when that was not the

[19] "10 facts on patient safety," World Health Organization (WHO), viewed 19 April 2019, https://www.who.int/features/factfiles/patient_safety/en/

[20] ibid

[21] "EMS: PS-10," Center for Patient Safety, viewed 19 April 2019, https://aams.org/wp-content/uploads/2016/02/EMSFORWARD-PS-10.pdf

case. Another way in which AUDREY can increase patient safety outcomes is through hazard identification. However, this was only partially evaluated during AHE because AUDREY was not able to provide additional information about the hazard.

Decision-support Outcomes

As previously discussed, paramedics operate in a fast-paced environment where they are required to make quick decisions often with limited information. There is a limit on the number of smart decisions that a human can make in a certain amount of time. This is called decision fatigue and it affects everyone regardless of how smart or hard-working. Decision fatigue refers to the "deteriorating quality of decisions made by an individual, after continuously making decisions."[22] Paramedics are especially vulnerable due to the frequency of pressure decisions they are required to make.[23] Further, almost any decision-making or other task requiring self-control will "drain [an individual's] reserves of mental energy."[24]

AUDREY is intended to be able to support paramedics in the decisions that they must make, which may help increase provider's mental energy and allow them to make better decisions. In particular, AI could support destination and routing decisions and medication and treatment plan decisions. It can also assess the capabilities of hospitals, paramedic physiological data and completeness of data. If AUDREY or another AI system proves to be able to perform these capabilities in a real-world environment, there could be many positive implications for the standard of patient care while also significantly reducing paramedic stress level and decision fatigue. However, AUDREY was either unable to, or inconsistent in, meeting most of these objectives. Though results indicated that AUDREY was successful in recognizing and transcribing basic patient data such as patient age, gender and symptoms, and pulse, blood pressure, respirations, and oximetry data, its assessment capabilities fell short. Specifically, this included assessing the completeness of data and prompting the paramedic for missing data, assessing patient data with regards to I&C, prompting paramedic for I&C, confirmation of the paramedic plan, right patient, dose, route and time, and confirmation of medication, among others. That said, AUDREY had some success in confirming "right drug" and recognizing images, as discussed previously.

Overall, the success of AUDREY in supporting decisions is highly dependent upon network connectivity, the ability of AUDREY to not only recognize and transcribe but also assess data, and the ability of paramedics to be able to efficiently and effectively use the technology in daily operations. If the WAMS device falls in and out of connection in a rural area or from moving from inside to outside of the ambulance, for example, using the device is more likely to delay patient treatment and other critical paramedic processes.

[22] "Intelligent Economist," Decision Fatigue, viewed 19 April 2019, https://www.intelligenteconomist.com/decision-fatigue/

[23] "When Thinking is Hard: Managing Decision Fatigue," EMS World, viewed 19 Aril 2019, https://www.emsworld.com/article/10687160/when-thinking-hard-managing-decision-fatigue

[24] "When Thinking is Hard: Managing Decision Fatigue," EMS World, viewed 19 Aril 2019, https://www.emsworld.com/article/10687160/when-thinking-hard-managing-decision-fatigue

Information Fusion Outcomes

Information fusion involves integrating information and data from multiple sources "to produce specific and comprehensive unified estimates about an entity, activity or event."[25] The primary goal of data/information fusion is to "provide estimates of a specific condition in the real-world using observable data in the most optimal manner possible."[26] Thus, information fusion is very useful in the paramedic environment as providers are required to synthesize a large amount of life-saving data in a short amount of time, which can lead to information overload.

Artificial intelligence could provide significant enhancements to responder information fusion capabilities. AUDREY is designed to assist first responders in synthesizing high-level data while at the scene of an emergency. It takes all the relevant data related to the incident and uses it to help responders make quicker decisions in these crucial moments. Specifically, AUDREY provides situational awareness during an incident, connecting first responders with data from other sources. During AHE, AUDREY was successful in recognizing and ingesting call information from dispatch and transmitting the standing orders to the paramedics. However, as mentioned previously, AUDREY seemed to face challenges with assessing the information and data and aggregating it into actionable recommendations and reports. In particular, various AUDREY objectives focus on utilizing the information it has gathered to populate a patch form (example patch form included in Appendix C). Likely due to speech processing and/or connectivity issues, AUDREY was not able to successfully complete a patch form with all patient data during AHE. In some attempts to populate the form, AUDREY provided some correct data, but the remaining parts of the form were filled with old data from a previous use case. In addition, there were concerns regarding potential delays if paramedics and physicians have to edit the data AUDREY populated in the patch form. Participating paramedics and physicians strongly agreed that having information from AUDREY that they do not currently have access to (e.g., picture of an EKG) would be extremely beneficial.

Communications Outcomes

Effective and efficient communications are important for any first responder discipline, but especially critical for emergency medical calls. AUDREY offers a potential solution to responder communication issues through AI. For paramedics, the focus is primarily on the communication that occurs between the paramedic and the physician. As discussed, prior to taking next steps in treatment, paramedics may be required to call and consult a physician. An AI system, such as AUDREY, could recognize first responder related terms and record pertinent information regarding the incident and patient during response. In turn, that system would then populate this information into a patch form that can be easily and quickly sent to a physician for approval. If accurately populated, this could eliminate confusion between paramedics and physicians. AUDREY faced challenges in correctly populating the patch form (as discussed previously) and there were some concerns regarding this capability from participating physicians. One concern was that the patch form would still not provide enough information to the physician for him or her to make a judgment call on a treatment plan, further stating that

[25] "What is MIF?" University of Buffalo, viewed 19 April 2019, http://www.buffalo.edu/cmif/center/what-is-MIF.html
[26] ibid

they also need to be able to see what is happening with image and/or video data (e.g., visual defibrillator data). The treatment of emergency patients is a complex process involving a great deal of information gathering. AUDREY demonstrated there are some aspects where AGI can benefit paramedic operations, but there are still challenges when dealing with complex cases. Overall, AHE validated the idea that AI systems will be a powerful value add to critical medical call communications; however, AI is unlikely to completely replace direct communications.

Effective communication often requires having strong network connectivity. During AHE, AUDREY would drift in and out of connection. For instance, during observation of Use Case 5, when paramedics were required to leave the ambulance to respond to the patient, they lost connection upon exiting the vehicle and were not able to regain connection for a significant amount of time once back inside. Further, as discussed previously, if the WAMS device easily falls in and out of connection, using the device could potentially delay patient treatment and other critical paramedic processes.

Process Outcomes

AUDREY was designed to assist responders in synthesizing high-level data while at the scene of an emergency. In the field, AUDREY should be viewed as just that – an assistant to paramedics; thus, the goal is that paramedics should not have to drastically modify their current processes, but rather focus on integrating AUDREY into what they already do. However, with integration of any new technology, process or system comes with at least a minimal level of adjustment. For instance, there may need to be additions or modifications to the ambulance or response vehicle, such as a server or modem that provides strong network connection for AUDREY. In addition, AUDREY users will need to learn how to effectively use and interact with the technology. Specifically, during AHE, it was apparent that the participating paramedics were having trouble interacting with AUDREY. One participating physician observed that it seemed like the paramedics were having to adapt to fit AUDREY rather than the technology fitting into their current processes. Future development should actively engage responders at the beginning to appreciate the working conditions and adapt the technology around that work environment. Another consideration is that policy changes may be needed to safely and meaningfully integrate AI. For instance, there may be issues with patient privacy and data access, among other regulatory and legal concerns.

Additional Considerations

Many of the challenges identified during AHE could be (or have the potential to be) addressed with additional training and development of AUDREY. Despite these challenges, AHE resulted in a number of successes. AHE was not designed to be a product test of a fully-developed system, but instead to explore how AI may enhance responder operations. Paramedics, physicians, municipal leaders and project staff were able to preview the significant prospects of AI support to operations. Further, AHE prompted the consideration of other emergency response problems that AI could address. The AHE scenario was focused on a narrowly-defined call for service. For example, what if the situation was instead a mass casualty incident with many multiple patients? What other data could enhance operations and how might it be accessed and transmitted to provide benefit? Although the system was not able to address all of the

objectives as originally envisioned, AUDREY demonstrated progress in addressing some of the paramedic needs.

Further, AHE fostered the development of cross-border relationships with government entities and private industry. Hastings County was extremely generous in the provision of HQPS staff and paramedics to plan AHE and evaluate AUDREY, as well as with facilities and equipment. HQPS Chief Doug Socha spent a significant amount of time preparing training data for AUDREY to consume, reviewing project documents, and arranging all logistics for project meetings. Much of the success resulting from AHE is a direct result of his willing involvement. Likewise, InterDev staff provided invaluable technical expertise throughout the preparation and execution of the experiment.

Based upon these outcomes, AHE achieved its objectives of demonstrating the potential benefit of AI for emergency response operations and fostering continued collaboration between DHS S&T and DRDC CSS in the development of emergency response technology solutions. Participants in AHE were able to experience how AI could impact response operations and consider future applications for AI in the field of emergency response. In addition, due to AHE, DHS S&T and DRDC CSS have created stronger connections and the foundation for future projects.

Appendix A: AHE Objectives by Phase

Table 10. AHE Objectives by Phase

Phase	Objective	Obj #	REVISIONS	USE CASES					
Dispatch				**AHE-1**	**AHE-2**	**AHE-3**	**AHE-4**	**AHE-5**	**AHE-6**
D1.1.1	AUDREY Recognizes Data from PSAP Alert	D1	Partial objective; Data obtained from InterDe		●	○	○	○	○
D1.1.1	AUDREY Transcribes Alert Data	D2	Current objective		●	○	○	○	○
En Route				**AHE-1**	**AHE-2**	**AHE-3**	**AHE-4**	**AHE-5**	**AHE-6**
E2.1.1	AUDREY Recognizes Pt Age	E1	Current objective		●	○	●	○	○
E2.1.1	AUDREY Transcribes Pt Age	E2	Current objective		●	○	●	○	○
E2.1.2	AUDREY Recognizes Pt Gender	E3	Current objective		●	○	●	○	○
E2.1.2	AUDREY Transcribes Pt Gender	E4	Current objective		●	○	●	○	○
E2.1.3	AUDREY Recognizes Pt Symptoms	E5	Current objective		●	○	●	●	○
E2.1.3	AUDREY Transcribes Pt Symptoms	E6	Current objective		●	○	●	●	○
E2.2.1	AUDREY Recognizes Data from Card 1	E7	Partial objective; Limited Card 1 data provided from InterDev		●	○	●	○	○
E2.2.1	AUDREY Transcribes Data from Card 1	E8	Partial objective; Limited Card 1 data provided from InterDev		●	○	●	○	○
E2.3.1	AUDREY Searches Address Call History	E9	Current objective		●	○	●	●	○
E2.3.1	AUDREY Transmits Address Call Data	E10	Current objective		●	○	●	●	○
E2.3.2	AUDREY Searches Pt Health History	E11	Deferred objective		○	○	○	○	○
E2.3.2	AUDREY Transmits Pt Health Data	E12	Deferred objective		○	○	○	○	○
E2.4.1	AUDREY Identifies Relevant Standing Orders	E13	Partial objective; Providing confidence level, not identification		●	○	●	○	○
E2.4.1	AUDREY Transmits Standing Orders	E14	Partial objective; Providing confidence level, not identification		●	○	●	○	○
E2.5.1	AUDREY Accesses Road Status Information	E15	Deferred objective			○			
E2.5.1	AUDREY Calculates Route to Call Address	E16	Deferred objective			○			

Assess				AHE-1	AHE-2	AHE-3	AHE-4	AHE-5	AHE-6
A3.1.2	AUDREY Recognizes Hazard Info	A1	Current objective					●	
A3.1.2	AUDREY Ingests Images or Real-Time Video Data	A2	Current objective					●	
A3.1.2	AUDREY Recognizes Images or Real-Time Video Data	A3	Current objective					●	
A3.2.1	AUDREY Identifies Relevant ERG Guidance	A4	Current objective					●	
A3.2.1	AUDREY Transmits Pertinent ERG Guidance	A5	Current objective					●	
A3.3.1	AUDREY Recognizes Initial CTAS Assessment	A6	Current objective		●	○	○	○	○
A3.3.1	AUDREY Records Initial CTAS Assessment	A7	Current objective		●	○	○	○	○
A3.3.2	AUDREY Recognizes Pt History	A8	Current objective		●	○	●	○	○
A3.3.2	AUDREY Records Pt History	A9	Current objective		●	○	●	○	○
A3.3.2	AUDREY Records Metadata: Pt History	A10	Current objective		●	○	●	○	○
A3.3.2	AUDREY Populates Form: Pt History	A11	Current objective		●	○	●	○	○
A3.3.3	AUDREY Recognizes Past Med History	A12	Current objective		●	○	●	○	●
A3.3.3	AUDREY Records Past Med History	A13	Current objective		●	○	●	○	●
A3.3.3	AUDREY Records Metadata: Past Med History	A14	Current objective		●	○	●	○	●
A3.3.3	AUDREY Populates Form: Past Med History	A15	Current objective		●	○	●	○	●
A3.3.4	AUDREY Recognizes Medications	A16	Current objective		●	○	○	○	●
A3.3.4	AUDREY Records Medications	A17	Current objective		●	○	○	○	●
A3.3.4	AUDREY Records Metadata: Medications	A18	Current objective		●	○	○	○	●
A3.3.4	AUDREY Populates Form: Medications	A19	Current objective		●	○	○	○	●
A3.3.5	AUDREY Recognizes Allergies	A20	Current objective		●	○	○	○	○
A3.3.5	AUDREY Records Allergies	A21	Current objective		●	○	○	○	○
A3.3.5	AUDREY Records Metadata: Allergies	A22	Current objective		●	○	○	○	○
A3.3.5	AUDREY Populates Form: Allergies	A23	Current objective		●	○	○	○	○
A3.3.6	AUDREY Recognizes Physical Findings	A24	Current objective		●	○	○	○	○
A3.3.6	AUDREY Records Physical Findings	A25	Current objective		●	○	○	○	○
A3.3.6	AUDREY Records Metadata: Physical Findings	A26	Current objective		●	○	○	○	○

A3.3.6	AUDREY Populates Form: Physical Findings	A27	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Pulse Data	A28	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Blood Pressure Data	A29	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Pulse Oximetry Data	A30	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Blood Sugar Data	A31	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Temperature Data	A32	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Pupil Data	A33	Current objective		●	o	o	o	o
A3.3.7	AUDREY Recognizes Pt Skin Condition Data	A34	Current objective		●	o	o	o	o
A3.3.7	AUDREY Records Vitals	A35	Current objective		●	o	o	o	o
A3.3.7	AUDREY Records Metadata: Vitals	A36	Current objective		●	o	o	o	o
A3.3.7	AUDREY Populates Form: Vital Measurements	A37	Current objective		●	o	o	o	o
A3.4.2	AUDREY Recognizes Metadata: ECG 3-Lead	A38	Current objective		●	o	o	o	o
A3.4.2	AUDREY Records Metadata: ECG 3-Lead	A39	Current objective		●	o	o	o	o
A3.4.2	AUDREY Recognizes Metadata: EKG 12-Lead	A40	Current objective		●	●	o	o	o
A3.4.2	AUDREY Records Metadata: EKG 12-Lead	A41	Current objective		●	●	o	o	o

Treat				AHE-1	AHE-2	AHE-3	AHE-4	AHE-5	AHE-6
T4.1.1	AUDREY Assesses Completeness of Data	T1	Current objective		●	○	○	○	○
T4.1.1	AUDREY Prompts Paramedic for Missing Data	T2	Partial objective; Notification, but not prompt		●	○	○	○	○
T4.1.2	AUDREY Recognizes Pertinent Standing Order(s)	T3	Current objective		●	○	○	○	○
T4.1.3	AUDREY Recognizes Paramedic STEMI Assessment	T4	Current objective			●			
T4.1.3	AUDREY Records Paramedic STEMI Assessment	T5	Current objective			●			
T4.1.3	AUDREY Records Metadata: STEMI Assessment	T6	Current objective			●			
T4.1.4	AUDREY Recognizes I&C	T7	Partial objective; Recognizing select set of I&C		●	○	○	○	●
T4.1.4	AUDREY Assesses Pt Data wrt I&C	T8	Partial objective; Recognizing select set of I&C		●	○	○	○	●
T4.1.4	AUDREY Prompts Paramedic for I&C	T9	Current objective						●
T4.2.1	AUDREY Recognizes Paramedic Plan	T10	Rescinded objective; subsumed by other objectives		●	○	●	○	●
T4.2.1	AUDREY Confirms Paramedic Plan	T11	Rescinded objective; subsumed by other objectives		●	○	●	○	●
T4.2.2	AUDREY Confirms "Right Patient"	T12	Current objective		●	○	●	○	●
T4.2.2	AUDREY Confirms "Right Drug"	T13	Partial objective; confirmation of med, but no analysis		●	○	●	○	●
T4.2.2	AUDREY Recognizes Image	T14	Current objective		●	○	○	○	●
T4.2.2	AUDREY Confirms Medication	T15	Current objective		●	○	○	○	●
T4.2.2	AUDREY Confirms "Right Dose"	T16	Partial objective; repeat of dose, but no analysis		●	○	●	○	●
T4.2.2	AUDREY Confirms "Right Route"	T17	Partial objective; repeat of route, but no analysis		●	○	●	○	●
T4.2.2	AUDREY Confirms "Right Time"	T18	Partial objective; repeat of time, but no analysis		●	○	●	○	●
T4.2.3	AUDREY Records Medications Administered	T19	Current objective		●	○	○	○	○
T4.2.3	AUDREY Records Metadata: Medications Administered	T20	Current objective		●	○	○	○	○

T4.2.3	AUDREY Provides Medication Reminders (As Necessa	T21	Current objective		●	○	○	○	○
T4.2.4	AUDREY Records Physical Interventions	T22	Current objective		●	○	○	○	○
T4.2.4	AUDREY Records Metadata: Physical Interventions	T23	Current objective		●	○	○	○	○
T4.3.2	AUDREY Transmits Pt Data to Physician	T24	Current objective		●	○	○	○	○
T4.3.5	AUDREY Records Physician Orders	T25	Current objective		●	○	○	○	○
T4.3.5	AUDREY Recognizes Physician Orders	T26	Current objective		●	○	○	○	○
T4.3.5	AUDREY Communicates Physician Orders	T27	Current objective		●	○	○	○	○
T4.4.1	AUDREY Recognizes Second CTAS Assessment	T28	Current objective		●	○	○	○	○
T4.4.1	AUDREY Records Second CTAS Assessment	T29	Current objective		●	○	○	○	○
T4.5.1	AUDREY Recognizes Paramedic Baseline Data	T30	Rescinded; no longer testing paramedic vitals					○	○
T4.5.1	AUDREY Recognizes VitalTag ECG Data	T31	Current objective					●	●
T4.5.1	AUDREY Recognizes VitalTag Heart Rate Data	T32	Current objective					●	●
T4.5.1	AUDREY Recognizes VitalTag Paramedic Skin Temp	T33	Amended objective; patient vs paramedic skin temp					●	●
T4.5.1	AUDREY Recognizes VitalTag Ambient Temp	T34	Rescinded objective; Patch form/EPCR do not include this field					○	○
T4.5.1	AUDREY Recognizes VitalTag Respiratory Rate	T35	Current objective					●	●
T4.5.1	AUDREY Recognizes VitalTag Blood Oxygen Saturatio	T36	Current objective					●	●
T4.5.1	AUDREY Recognizes VitalTag Systolic Blood Pressure	T37	Current objective					●	●
T4.5.1	AUDREY Recognizes VitalTag Atmospheric Pressure	T38	Rescinded objective; Patch form/EPCR do not include this field					○	○
T4.5.1	AUDREY Records VitalTag Data	T39	Current objective					●	●
T4.5.1	AUDREY Assesses Paramedic Physiological Data	T40	Rescinded objective; no longer testing paramedic vitals					○	○
T4.5.1	AUDREY Alerts Based on Physiological Measurements	T41	Current objective					●	●

Transport (to Hospital)				AHE-1	AHE-2	AHE-3	AHE-4	AHE-5	AHE-6
H5.1.2	AUDREY Identifies Unit Location	H1	Deferred objective		◍	◍	○	○	○
H5.1.3	AUDRY Assesses Cardiac Capabilities of Hospitals	H2	Deferred objective			◍			
H5.1.5	AUDREY Accesses Road Status Information	H3	Deferred objective		◍	◍	○	○	○
H5.1.5	AUDREY Calculates ETA	H4	Deferred objective		◍	◍	○	○	○
H5.1.5	AUDREY Notifies Destination Hospital of ETA	H5	Deferred objective		◍	◍	○	○	○
H5.1.5	AUDREY Updates Hospital wrt ETA	H6	Deferred objective		◍	◍	○	○	○
H5.2.1	AUDREY Records Additional Medications	H7	Current objective		●	o	o	o	o
H5.2.1	AUDREY Records Metadata: Additional Medications	H8	Current objective		●	o	o	o	o
H5.2.2	AUDREY Records Additonal Physical Interventions	H9	Rescinded objective; No other physical interventions in MSEL						
H5.2.2	AUDREY Records Metadata: Additional Physical Interv	H10	Rescinded objective; No other physical interventions in MSEL						
H5.3.4	AUDREY Transmits Pt Data	H11	Current objective		●	o	o	o	o

Appendix B: T&E Plan Criteria

Table 1 shows the tests to be performed, applicable data elements, the analyses to be completed and results to be presented for each measure.

The listed data elements will be collected by a few means during the AHE. Data is collected by observation, recording time, survey/debrief following execution of use cases, and logs from JPL and Interdev of data exchanges and records. Data collection templates are included in Appendix C. These templates detail instructions on how and when to measure and record specific data elements during each use case. Data for VitalTag will be included in use cases 5 and 6.

Data to address the HSI assessment will be collected by direct observation of the use of the NGFR technologies, review of the various tasks and procedures that are performed by the EMS crew, and through survey and discussion following the use cases. The survey is provided in Appendix D. The data will be compiled into a report with topics for usability, error likelihood, time to perform, cognitive workload, physical workload, impact on staffing, safety and/or health hazards, user skills, training, wearability, information quality, communications quality, maintainability, and user acceptance.

There will be three data collectors assigned to perform this effort. One data collector will have a smartphone with the WAMS app installed for the purpose of recording information that is shared through WAMS. One data collector will be assigned to observe and gather HSI data during the event. The third data collector will have responsibility to obtain the remaining information. Data collectors will be positioned alongside the HQPS responders throughout the use cases.

Table 11. T&E Plan Criteria

Measure	Tests, Data Elements, Analyses/Results
Transmission: Success	**Test:** AUDREY completes the sharing of each data element x times out of y occurrences per use case
	Data Elements: Address Call Data, Pt Health Data, Standing Orders, ERG Guidance, Initial CTAS Assessment, Pt Data to Physician, Destination Hospital of ETA, Hospital on ETA Update, Pt Data
	Analyses/Results: % completed transmission, will have individual assessments for all individual data elements per use case and then a roll up of data across related data elements and use cases as appropriate

Transmission: Time	**Test:** Time from initiation of transmission until information reaches end user for each data element and instance in a use case
	Data Elements: Address Call Data, Pt Health Data, Standing Orders, ERG Guidance, Initial CTAS Assessment, Pt Data to Physician, Destination Hospital of ETA, Hospital on ETA Update, Pt Data
	Analyses/Results: Summary of transmission times for each data element with roll ups across related data elements and use cases as appropriate
Recognition: Accuracy	**Test:** AUDREY populates database for x times out of y occurrences per use case
	Data Elements: PSAP Alerts, Pt Age, Pt Gender, Pt Symptoms, Card 1, Hazard Info, Images (hazards), CTAS Assessment, Pt History, Past Medical History, Medications, Allergies, Physical Findings, Pulse, Blood Pressure, Pulse Oximetry, Blood Sugar, Temperature, Pupil, Skin Condition, EKG 3-Lead, EKG 12-Lead, Standing Orders, STEMI Assessment, I&C, Paramedic Plan, Images (medications), Physician Orders, Baseline Data, VitalTag ECG, VitalTag Heart Rate, VitalTag Skin Temp, VitalTag Ambient Temp, VitalTag Respiratory Rate, VitalTag Blood Oxygen Saturation, VitalTag Systolic Blood Pressure, and VitalTag Atmospheric Pressure
	Analyses/Results: % correct, will have individual assessments for x, y and z, data elements per use case, and then a roll up for data provided via electronic format and voice
Recording: Success	**Test:** AUDREY populates database for x times out of y occurrences per use case
	Data Elements: Pt History, Pt History Metadata, Past Med History, Past Med History Metadata, Medications, Medications Metadata, Allergies, Allergies Metadata, Physical Findings, Physical Findings Metadata, Vitals, Vitals Metadata, ECG 3-Lead Metadata, EKG 12-Lead Metadata, Paramedic STEMI Assessment, STEMI Assessment Metadata, Medications Administered, Medications Administered Metadata, Physical Interventions, Physical Interventions Metadata, Physician Orders, Second CTAS Assessment, VitalTag Data, Additional Medications, Additional Medications Metadata, Additional Physical Interventions, Additional Physical Interventions Metadata
	Analyses/Results: % correct, will have individual assessments for x, y and z, data elements per use case, and then a roll up for data provided via electronic format and voice

Transcription: Accuracy	**Test:** AUDREY provides correct data x times out of y times field is populated for some trials and may need to be considered an incomplete (either not all data included or not all is correct) so this may not be a binary value
	Data Elements: PSAP Alerts, Pt Age, Pt Gender, Pt Symptoms, Card 1, CTAS Assessment, Pt History, Past Medical History, Medications, Allergies, Physical Findings, (Pulse, Blood Pressure, Pulse Oximetry, Blood Sugar, Temperature, Pupil, Skin Condition), EKG 3-Lead, EKG 12-Lead, Standing Orders, STEMI Assessment, I&C, Paramedic Plan, Physician Orders, Baseline Data, VitalTag ECG, VitalTag Heart Rate, VitalTag Skin Temp, VitalTag Ambient Temp, VitalTag Respiratory Rate, VitalTag Blood Oxygen Saturation, VitalTag Systolic Blood Pressure, and VitalTag Atmospheric Pressure
	Analyses/Results: % correct, % partial
Transcription: Accuracy	**Test:** AUDREY provides correct data x times out of y times field is populated for some trials and may need to be considered an incomplete (either not all data included or not all is correct) so this may not be a binary value
	Data Elements: PSAP Alerts, Pt Age, Pt Gender, Pt Symptoms, Card 1, CTAS Assessment, Pt History, Past Medical History, Medications, Allergies, Physical Findings, (Pulse, Blood Pressure, Pulse Oximetry, Blood Sugar, Temperature, Pupil, Skin Condition), EKG 3-Lead, EKG 12-Lead, Standing Orders, STEMI Assessment, I&C, Paramedic Plan, Physician Orders, Baseline Data, VitalTag ECG, VitalTag Heart Rate, VitalTag Skin Temp, VitalTag Ambient Temp, VitalTag Respiratory Rate, VitalTag Blood Oxygen Saturation, VitalTag Systolic Blood Pressure, and VitalTag Atmospheric Pressure
	Analyses/Results: % correct, % partial
Search: Accuracy	**Test:** AUDREY correctly provides record x times out of y cases when it exists, confirm no false positives (provide record when none exist)
	Data Elements: Call History at Address, Prior Patient Medical History
	Analyses/Results: % correct
Identification: Accuracy	**Test:** AUDREY reports correct information for each data element x times out of y occurrences for each data element in the use case
	Data Elements: Standing Orders, ERG, Unit Location
	Analyses/Results: % correct with roll up across use cases as available
Assessment:	**Test:** AUDREY performs correct assessment of data element in

Accuracy	x times out of y expected occurrences in the use case
	Data Elements: Completeness of Data, Pt Data I&C, Physiological Data (VitalTag), Cardiac Capable Hospitals, Road Status Information
	Analyses/Results: % correct with roll up across use cases as available
Prompt: Accuracy	**Data Elements:** Missing Data, I&C, Medications
	Analyses/Results: % correct with roll up across use cases as available
	Test: AUDREY confirms the data elements x times out of y expected occurrences per use case
Confirmation: Accuracy	**Test:** AUDREY confirms the data elements x times out of y expected occurrences per use case
	Data Elements: Paramedic Plan, "Right Patient", "Right Drug", "Right Dose", "Right Route", "Right Time"
	Analyses/Results: % correct, will have individual assessments for x, y and z, data elements per use case, and then a roll up for data across data elements and use cases as appropriate
Calculation: Accuracy	**Test:** AUDREY provides correct data x times out of y times field is populated
	Data Elements: Transmits Standing Orders, Calculates ETA
	Analyses/Results: % correct each data element per use case and then a roll up for data across use cases as appropriate
Audio: Clarity	**Test:** User feedback on whether the message was understandable or unclear for each occurrence when AUDREY is to communicate to user, Request explanations for failures
	Data Elements: Prompts Paramedic for Missing Data, Prompts Paramedic for I&C, Confirms Paramedic Plan, Confirms "Right Patient", Confirms "Right Drug", Confirms "Right Dose", Confirms "Right Route", Confirms "Right Time", Provides Medication Reminders (As Necessary), Communicates Physician Orders, Alerts Based on Physiological Measurements
	Analyses/Results: Provide frequencies of understanding for each data element and roll up across data elements, provide user responses on any failures

Visual: Clarity	**Test:** User feedback on whether the information was readable or unclear for each occurrence, request explanations for failures
	Data Elements: Address Call Data Transmission, Pt Health Data Transmission, Standing Orders Transmission, Pertinent ERG Guidance Transmission, Initial CTAS Assessment Transcription, Pt Data to Physician Transmission, Destination Hospital of ETA Notification, Hospital on ETA Update, Pt Data Transmission, Alert Data Transcription, Pt Age Transcription, Pt Gender Transcription, Pt Symptoms Transcription, Data from Card 1 Transcription, Pt History in Form, Past Med History in Form, Medications in Form, Allergies in Form, Physical Findings in Form, Vital Measurements in Form
	Analyses/Results: Provide frequencies of readability for each data element and roll up across data elements, provide user responses on any failures
Ingestion of Images/ Video: Success	**Test:** Images are captured by AUDREY in the use case x times out of y attempts for each data element
	Data Elements: Images of Hazard Labels, Images of Medication Labels
	Analyses/Results: % of time image capture is obtained for each data element with a roll up across use cases where appropriate

Appendix C: Patch Form

REGIONAL PARAMEDIC PROGRAM FOR EASTERN ONTARIO

Patch Form # 1-

Date: _____ Time : _____ Paramedic #:_____ ☐ ACP ☐ PCP

Pt Age: _____ Sex: ☐ M ☐ F Weight: _____

History:

Past Med History:

Medications:

Allergies:

Physical Examination:

BP: ____/_____

HR: _____

RR: _____

Sat.: _____

GCS: _____

Temp: _____

BS: _____

Skin: _____

Treatment(s) provided by Paramedic and Response:

Physician Orders:

Paramedic Repeated Orders ☐ **Please Review (explain on back): ☐**

Receiving Hospital:	**ETA**

MD Name (Print)	**CPSO #**	**MD Signature**

Revised: November 22, 2017

Appendix D: List of Acronyms

AHE	AUDREY Hastings Experiment
ALS	Advanced Life Support
API	Application Programming Interface
AUDREY	Assistant for Understanding Data through Reasoning, Extraction, and sYnthesis
AVL	Automated Vehicle Location
BLS	Basic Life Support
BP	Blood Pressure
CAD	Computer Aided Dispatch
CSS	Centre for Security Science
CTAS	Canadian Triage Acuity Scale
DHS	U.S. Department of Homeland Security
DPCI	Dispatch Priority Card Index
DRDC	Defence Research and Development Canada
ECG	Electro-cardiogram
EKG	Electro-cardiogram
EMS	Emergency Medical Service
ERG	Emergency Response Guide for Hazardous Materials
ETA	Estimated Time of Arrival
GPS	Global Positioning System
HQPS	Hastings-Quinte Paramedic Service
HR	Heart Rate
I&C	Indications and Contraindications
Interdev	Interdev Technologies Inc.
IoT	Internet of Things
JPL	Jet Propulsion Laboratory
KPI	Key Performance Indicator
LTE	Long-Term Evolution
MQTT	Message Queuing Telemetry Transport
NASA	National Aeronautics and Space Administration
NGFR	Next Generation First Responder Program
O2	Dissolved Oxygen
OGC	Open Geospatial Consortium
OS	Operating System
PCR	Patient Care Record
PHI	Personal Health Information
PNNL	Pacific Northwest National Laboratory
PPE	Personal Protective Equipment
PSAP	Public Safety Answering Point
Pt	Patient
PS	Paramedic Service
REST	Representational State Transfer

RR	Respiration Rate
SaaS	Software as a Solution
S&T	Science and Technology Directorate
STEMI	ST-segment Elevation Myocardial Infarction
TCP/IP	Transmission Control Protocol/Internet Protocol
UI	User Interface
WAMS	Wireless Alert Messaging System

Appendix E: Diagram of EMS Call by Use Case

The figures below provide a visual depiction of the standard EMS call and how AUDREY and other technologies fit into this process. Each figure represents one of the six use cases. The AUDREY-level test objectives are symbolized in the figures by the objective number identified in Appendix X. Further, the objective bubbles are color-coded to indicate whether it is a primary or secondary objective for said use case. As a note, AHE-1 is a current standard EMS call and does not include AUDREY; thus, there are no AUDREY objectives.

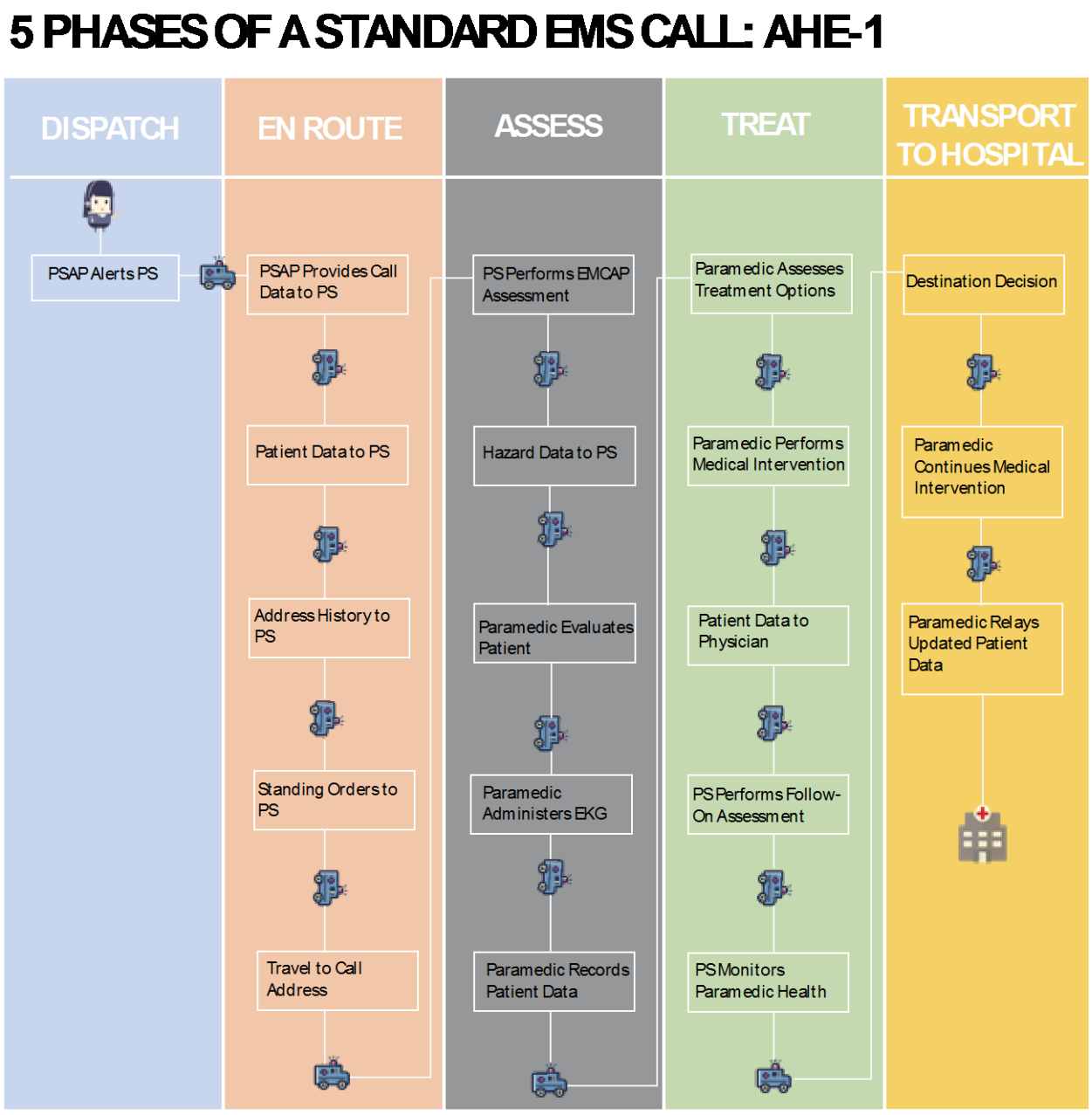


Figure 15. Use Case 1 Diagram

Figure 3: *5 Phases of a Standard EMS Call: AHE-2*

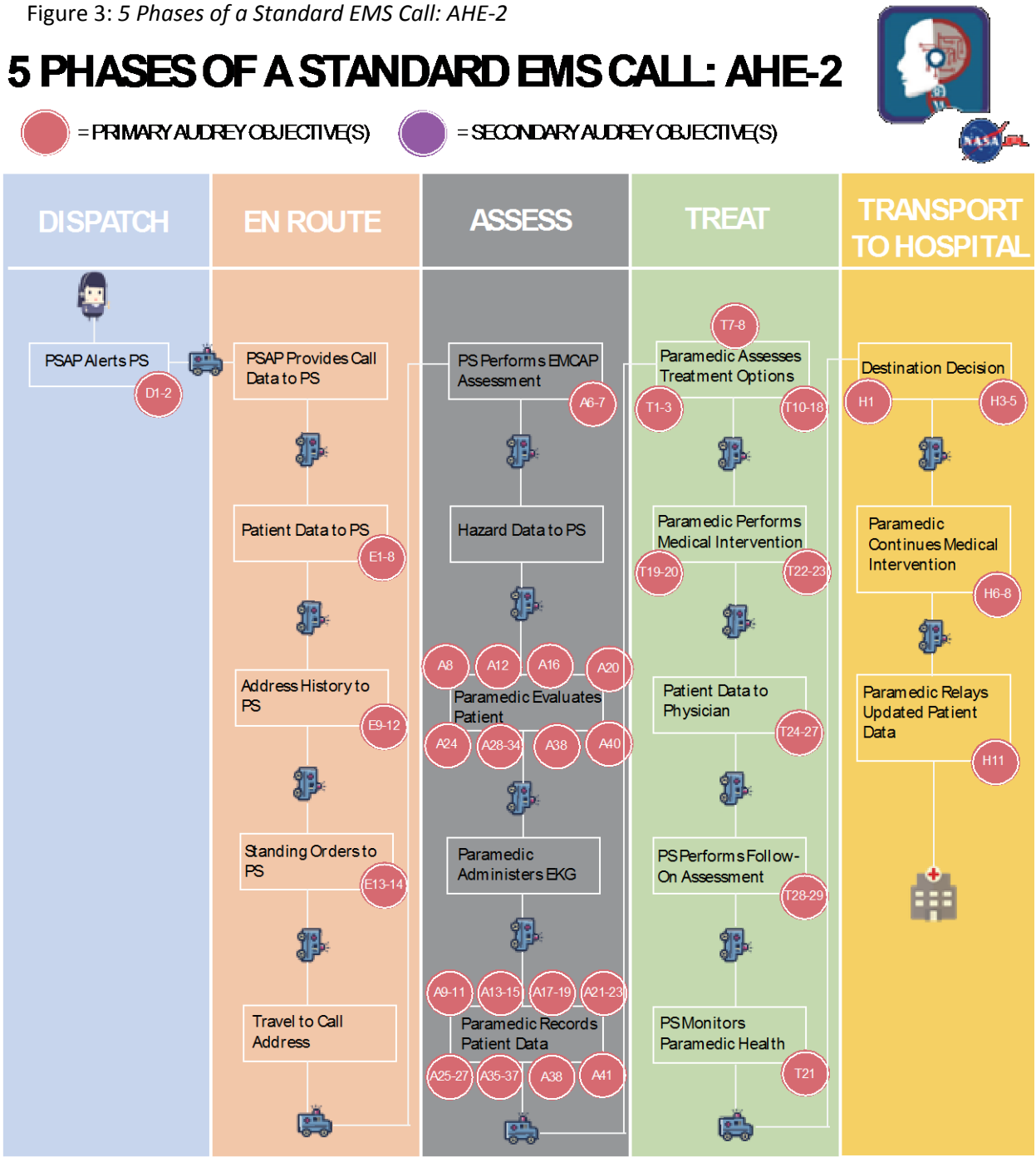


Figure 16. AUDREY Objectives for Use Case 2

Figure 4: *5 Phases of a Standard EMS Call: AHE-3*

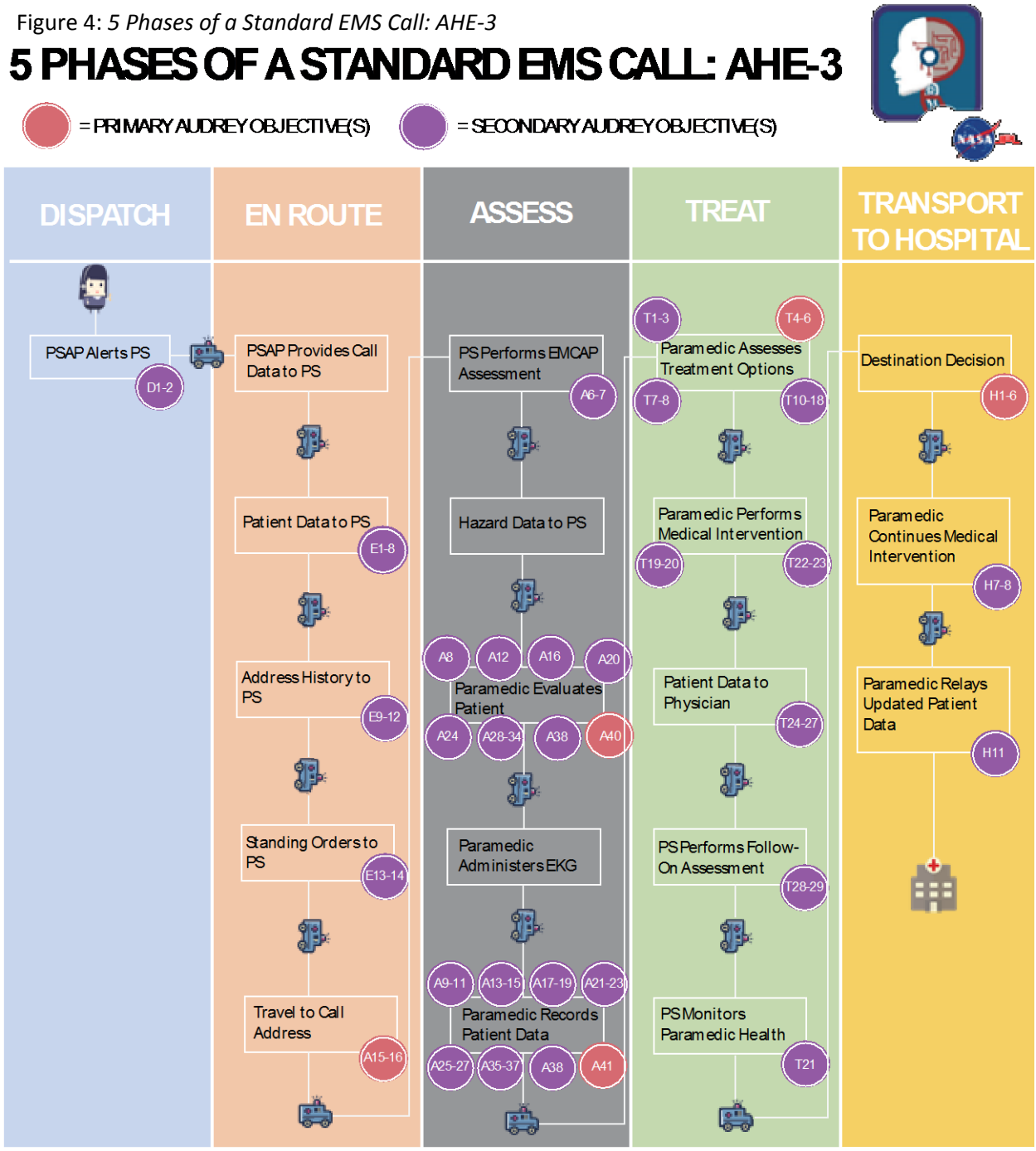


Figure 17. AUDREY Objectives for Use Case 3

Figure 5: *5 Phases of a Standard EMS Call: AHE-4*

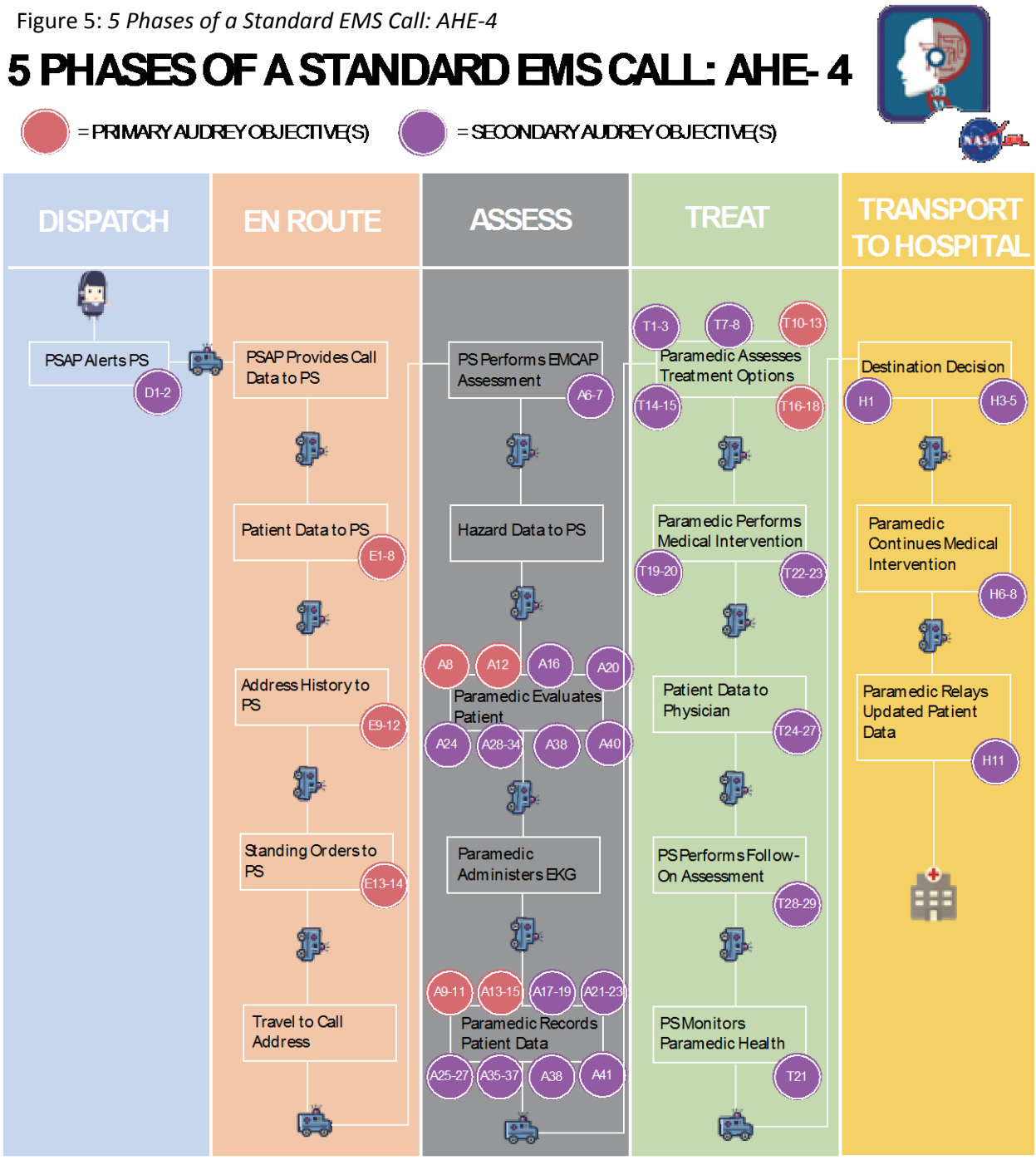


Figure 18. AUDREY Objectives for Use Case 4

Figure 6: *5 Phases of a Standard EMS Call: AHE-5*

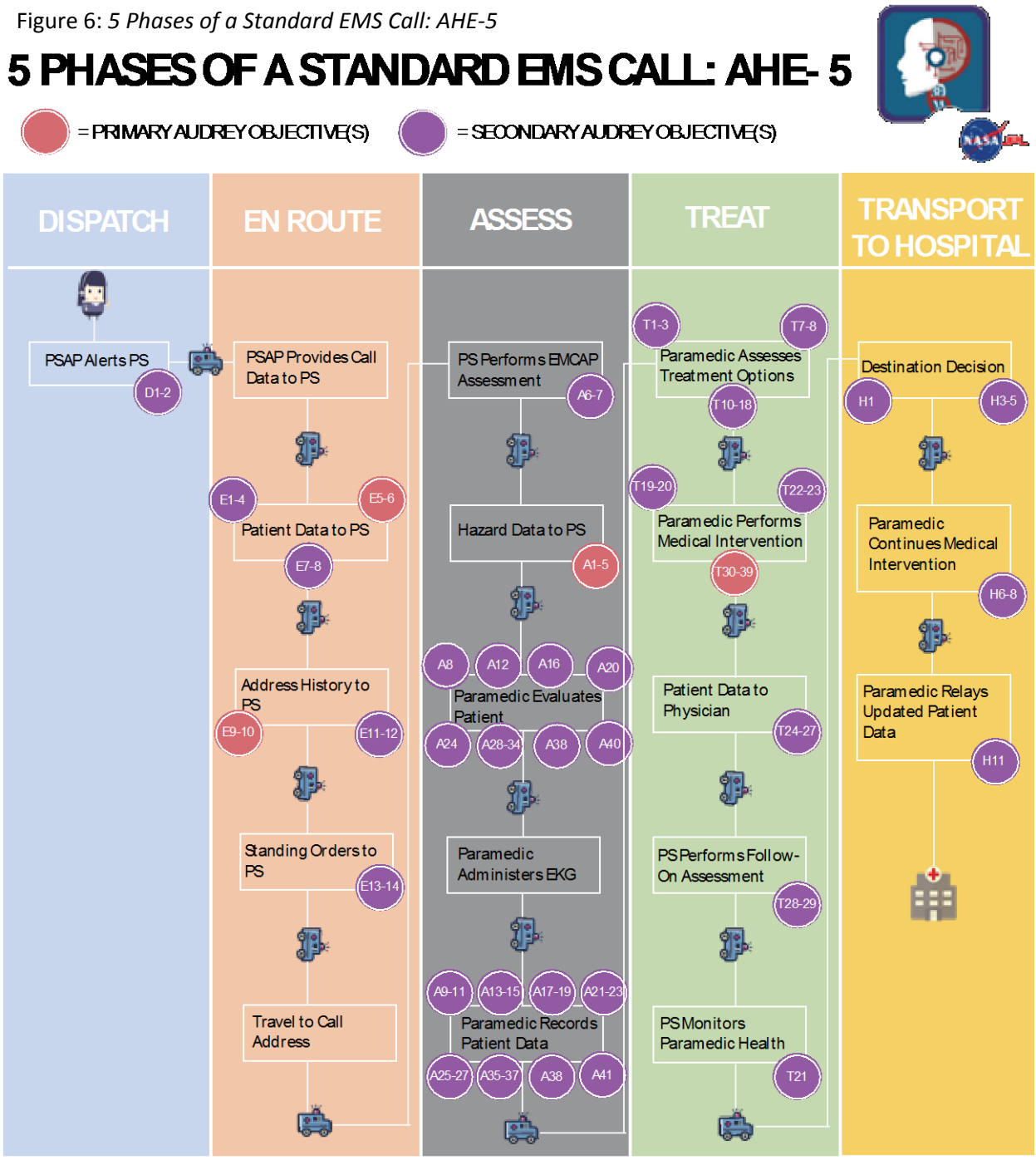


Figure 19. AUDREY Objectives for Use Case 5

Figure 7: *5 Phases of a Standard EMS Call: AHE-6*

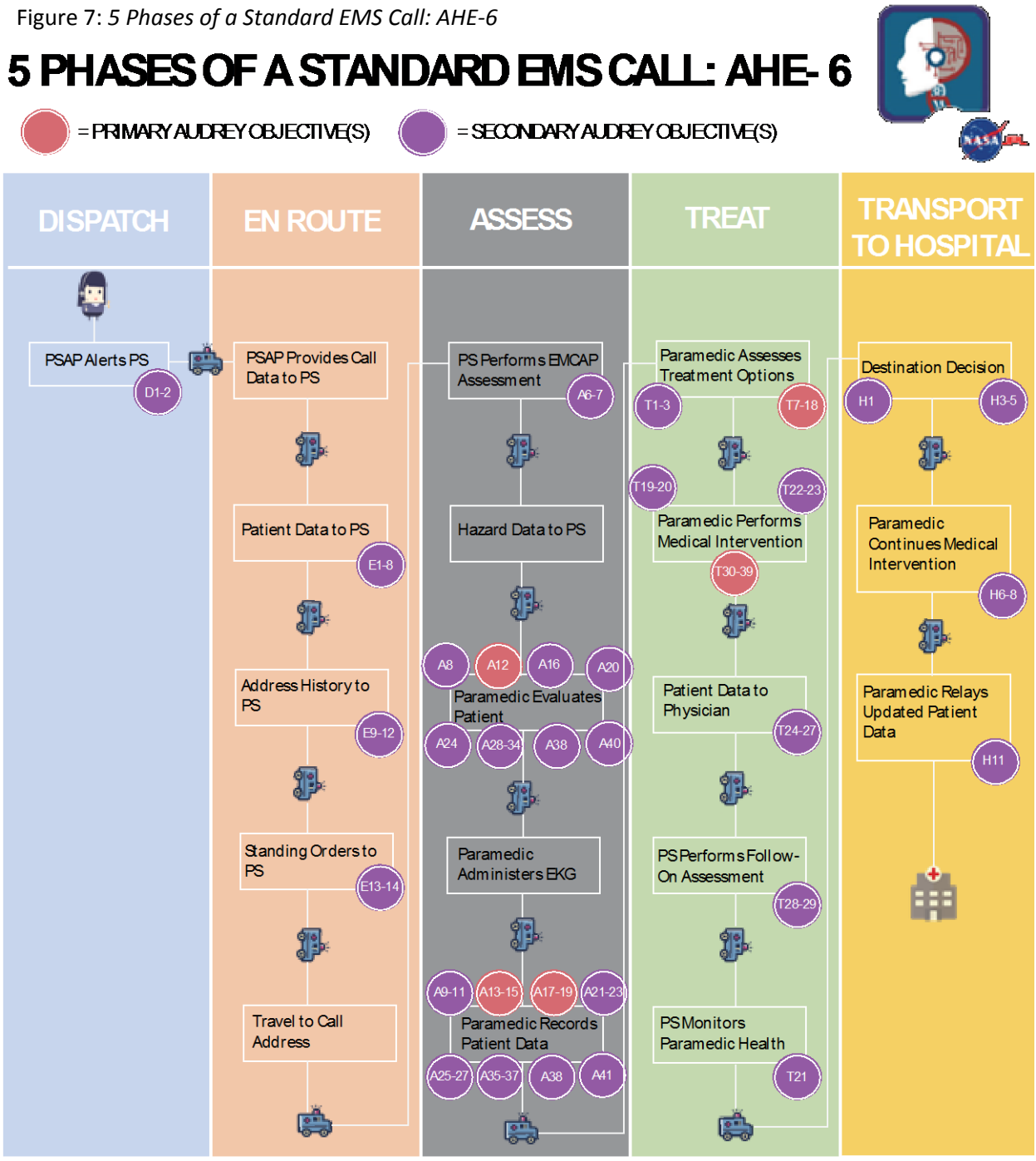


Figure 20. AUDREY Objectives for Use Case 6

Appendix F: Test Objectives Matrix

The table below lists the test objectives for AHE that are applicable to AUDREY. The objective identifier (#) is an alpha numeric value. The letter describes the phase of the EMS response that it pertains to (D for Dispatch, E for En route, A for Assessment, T for Treatment, and H for Hospital transport). The numeral is assigned in incremental order of occurrence within the use cases.

Table 12. AHE Test Objectives

Objective	#	Transmission: Success	Transmission: Time	Recognition: Accuracy	Recording: Success	Transcription: Accuracy	Search: Accuracy	Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy	Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
AUDREY Recognizes Data from PSAP Alert	D1			X											
AUDREY Transcribes Alert Data	D2					X								X	
AUDREY Recognizes Pt Age	E1			X											
AUDREY Transcribes Pt Age	E2					X								X	
AUDREY Recognizes Pt Gender	E3			X											
AUDREY Transcribes Pt Gender	E4					X								X	
AUDREY Recognizes Pt Symptoms	E5			X											
AUDREY Transcribes Pt Symptoms	E6					X								X	
AUDREY Recognizes Data from Card 1	E7			X											

Objective	#	Transmission: Success	Transmission: Time Recognition: Accuracy	Recording: Success Transcription: Accuracy	Search: Accuracy Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
AUDREY Transcribes Data from Card 1	E8			X						X	
AUDREY Searches Address Call History	E9				X						
AUDREY Transmits Address Call Data	E10	X	X							X	
AUDREY Searches Pt Health History	E11				X						
AUDREY Transmits Pt Health Data	E12	X	X							X	
AUDREY Identifies Relevant Standing Orders	E13					X					
AUDREY Transmits Standing Orders	E14	X	X							X	
AUDREY Identifies Relevant Standing Orders	E15					X					
AUDREY Transmits Standing Orders	E16							x		X	
AUDREY Recognizes Hazard Info	A1		X								
AUDREY Ingests Images or Real-Time Video Data	A2										X
AUDREY Recognizes Images	A3		X								

Objective	#	Transmission: Success	Transmission: Time	Recognition: Accuracy	Recording: Success	Transcription: Accuracy	Search: Accuracy	Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy	Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
or Real-Time Video Data															
AUDREY Identifies Relevant Guidance	A4							X							
AUDREY Transmits Pertinent ERG Guidance	A5	X	X											X	
AUDREY Recognizes Initial CTAS Assessment	A6			X											
AUDREY Transcribes Initial CTAS Assessment	A7	X	X											X	
AUDREY Recognizes Pt History	A8			X											
AUDREY Records Pt History	A9				X										
AUDREY Records Metadata: Pt History	A10				X										
AUDREY Populates Form: Pt History	A11					X								X	
AUDREY Recognizes Past Med History	A12			X											
AUDREY Records Past Med History	A13				X										
AUDREY Records Metadata: Past Med History	A14				X										
AUDREY Populates Form: Past	A15					X								X	

Objective	#	Transmission: Success	Transmission: Time Recognition:	Accuracy	Recording: Success Transcription:	Accuracy	Search: Accuracy Identification:	Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation:	Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
Med History															
AUDREY Recognizes Medications	A16			X											
AUDREY Records Medications	A17				X										
AUDREY Records Metadata: Medications	A18				X										
AUDREY Populates Form: Medications	A19					X								X	
AUDREY Recognizes Allergies	A20			X											
AUDREY Records Allergies	A21				X										
AUDREY Records Metadata: Allergies	A22				X										
AUDREY Populates Form: Allergies	A23					X								X	
AUDREY Recognizes Physical Findings	A24			X											
AUDREY Records Physical Findings	A25				X										
AUDREY Records Metadata: Physical Findings	A26				X										
AUDREY Populates Form: Physical Findings	A27					X								X	
AUDREY Recognizes Pt Pulse	A28			X											

Objective	#	Transmission: Success	Transmission: Time Recognition: Accuracy	Recording: Success Transcription: Accuracy	Search: Accuracy Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
Data											
AUDREY Recognizes Pt Blood Pressure Data	A29		X								
AUDREY Recognizes Pt Pulse Oximetry Data	A30		X								
AUDREY Recognizes Pt Blood Sugar Data	A31		X								
AUDREY Recognizes Pt Temperature Data	A32		X								
AUDREY Recognizes Pt Pupil Data	A33		X								
AUDREY Recognizes Pt Skin Condition Data	A34		X								
AUDREY Records Vitals	A35			X							
AUDREY Records Metadata: Vitals	A36			X							
AUDREY Populates Form: Vital Measurements	A37				X					X	
AUDREY Recognizes Metadata: ECG 3-Lead	A38		X								
AUDREY Records Metadata: ECG 3-Lead	A39			X							
AUDREY Recognizes	A40		X								

Objective	#	Transmission: Success	Transmission: Time	Recognition: Accuracy	Recording: Success	Transcription: Accuracy	Search: Accuracy	Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy	Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
Metadata: ECG 12-Lead															
AUDREY Records Metadata: EKG 12-Lead	A41				X										
AUDREY Assesses Completeness of Data	T1								X						
AUDREY Prompts Paramedic for Missing Data	T2									X			X		
AUDREY Recognizes Pertinent Standing Order(s)	T3			X											
AUDREY Recognizes Paramedic STEMI Assessment	T4			X											
AUDREY Records Paramedic STEMI Assessment	T5				X										
AUDREY Records Metadata: STEMI Assessment	T6				X										
AUDREY Recognizes I&C	T7			X											
AUDREY Assesses Pt Data with regard to I&C	T8								X						
AUDREY Prompts Paramedic for I&C	T9									X			X		
AUDREY Recognizes Paramedic Plan	T10			X											
AUDREY Confirms Paramedic	T11										X		X		

Objective	#	Transmission: Success	Transmission: Time Recognition: Accuracy	Recording: Success Transcription: Accuracy	Search: Accuracy Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
Plan											
AUDREY Confirms "Right Patient"	T12						X		X		
AUDREY Confirms "Right Drug"	T13						X		X		
AUDREY Recognizes Image	T14		X								X
AUDREY Confirms Medication	T15						X				
AUDREY Confirms "Right Dose"	T16						X		X		
AUDREY Confirms "Right Route"	T17						X		X		
AUDREY Confirms "Right Time"	T18						X		X		
AUDREY Records Medications Administered	T19			X							
AUDREY Records Metadata: Medications Administered	T20			X							
AUDREY Provides Medication Reminders (As Necessary)	T21					X			X		
AUDREY Records Physical Interventions	T22			X							
AUDREY Records Metadata: Physical Interventions	T23			X							

Objective	#	Transmission: Success	Transmission: Time Recognition: Accuracy	Recording: Success Transcription: Accuracy	Search: Accuracy Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
AUDREY Transmits Pt Data to Physician	T24	X	X							X	
AUDREY Records Physician Orders	T25			X							
AUDREY Recognizes Physician Orders	T26		X								
AUDREY Communicates Physician Orders	T27								X		
AUDREY Recognizes Second CTAS Assessment	T28		X								
AUDREY Records Second CTAS Assessment	T29			X							
AUDREY Recognizes Paramedic Baseline Data	T30		X								
AUDREY Recognizes VitalTag ECG Data	T31		X								
AUDREY Recognizes VitalTag Heart Rate Data	T32		X								
AUDREY Recognizes VitalTag Paramedic Skin Temp	T33		X								
AUDREY Recognizes VitalTag Ambient Temp	T34		X								
AUDREY Recognizes VitalTag	T35		X								

Objective	#	Transmission: Success	Transmission: Time Recognition: Accuracy	Recording: Success Transcription: Accuracy	Search: Accuracy Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
Respiratory Rate											
AUDREY Recognizes VitalTag Blood Oxygen Saturation	T36		X								
AUDREY Recognizes VitalTag Systolic Blood Pressure	T37		X								
AUDREY Recognizes VitalTag Atmospheric Pressure	T38		X								
AUDREY Records VitalTag Data	T39			X							
AUDREY Assesses Paramedic Physiological Data	T40					X					
AUDREY Alerts Based on Physiological Measurements	T41								X		
AUDREY Identifies Unit Location	H1				X						
AUDRY Assesses Cardiac Capabilities of Hospitals	H2					X					
AUDREY Accesses Road Status Information	H3					X					
AUDREY Calculates ETA	H4							X			
AUDREY Notifies Destination Hospital of ETA	H5	X	X							X	
AUDREY Updates Hospital	H6	X	X							X	

Objective	#	Transmission: Success	Transmission: Time Recognition: Accuracy	Recording: Success Transcription: Accuracy	Search: Accuracy Identification: Accuracy	Assessment: Accuracy	Prompt: Accuracy Confirmation: Accuracy	Calculation: Accuracy	Audio: Clarity	Visual: Clarity	AV Ingestion: Success
with regard to ETA											
AUDREY Records Additional Medications	H7			X							
AUDREY Records Metadata: Additional Medications	H8			X							
AUDREY Records Additional Physical Interventions	H9			X							
AUDREY Records Metadata: Additional Physical Interventions	H10			X							
AUDREY Transmits Pt Data	H11	X	X							X	