Applications of Advanced Network Infrastructure in Health and Disaster Management

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Project #1 "Next Generation Emergency Medical Dispatch Management"

The UAB project team has implemented a research test bed that mimics the operations of a 911 center to investigate the Next Generation Emergency Medical Dispatch Management environment. The group has defined five perspectives that correspond to five stakeholders in this community; we have expanded this list to include the direct users (stakeholders) of the current systems:

1. Medical Dispatching Center
    a. 911 Call Taker
    b. Dispatcher
2. Regional EMS Coordinating Center (e.g., BREMSS)
    a. BREMSS Director
    b. BREMSS Personnel
3. Ambulance Fleet Operator (e.g., Birmingham Fire & Rescue)
    a. Ambulance Company
    b. Paramedics/Emergency Personnel
4. Emergency Department
    a. Emergency Room Doctors
    b. Nursing and Supporting Staff
5. State-wide Disaster Response Center
    a. Emergency Management Association (EMA)

Along with the major stakeholders identified above, we also implemented a regional Emergency Patient database. Though the database has 3 logical sections, it is actually a single database on a SQL Server platform. Access to each logical section is maintained as follows:

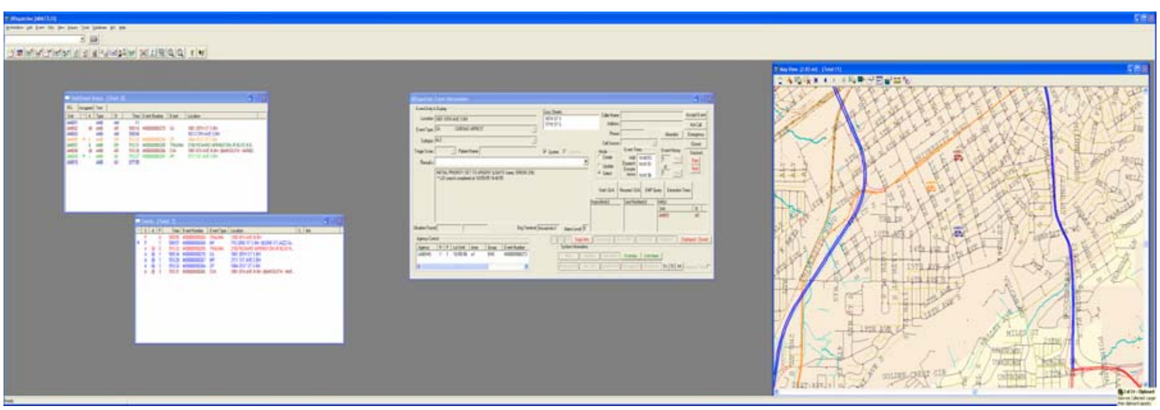
- Section 1: Location & Basic Medical Information –Read/write access to the 911 Dispatch and Emergency Medical Technician (EMT). This section would house basic medical information about the patient (e.g. the patient is a hemophiliac or a diabetic), as well as some information about the location of the call (e.g. hazardous chemicals are stored in the basement in a nearby building).
- Section 2: Current Clinical data –Read/write access to the EMT and ED physician. This division would store data transmitted by the EMT from the field. Besides text data, there would also be some audio and graphic files (ECGs, still images, video).
- Section 3: "High-Risk" data –Read-only access to the ED physician, write access to the Medical Record Department for updates. This would be information stored with prior consent of the patient, and would help the Emergency Department (ED) physician to provide medical advice to the EMT while the patient is in transit.

All changes and access requests will be time-stamped and logged.

Figure #1 I/CAD Workstation:

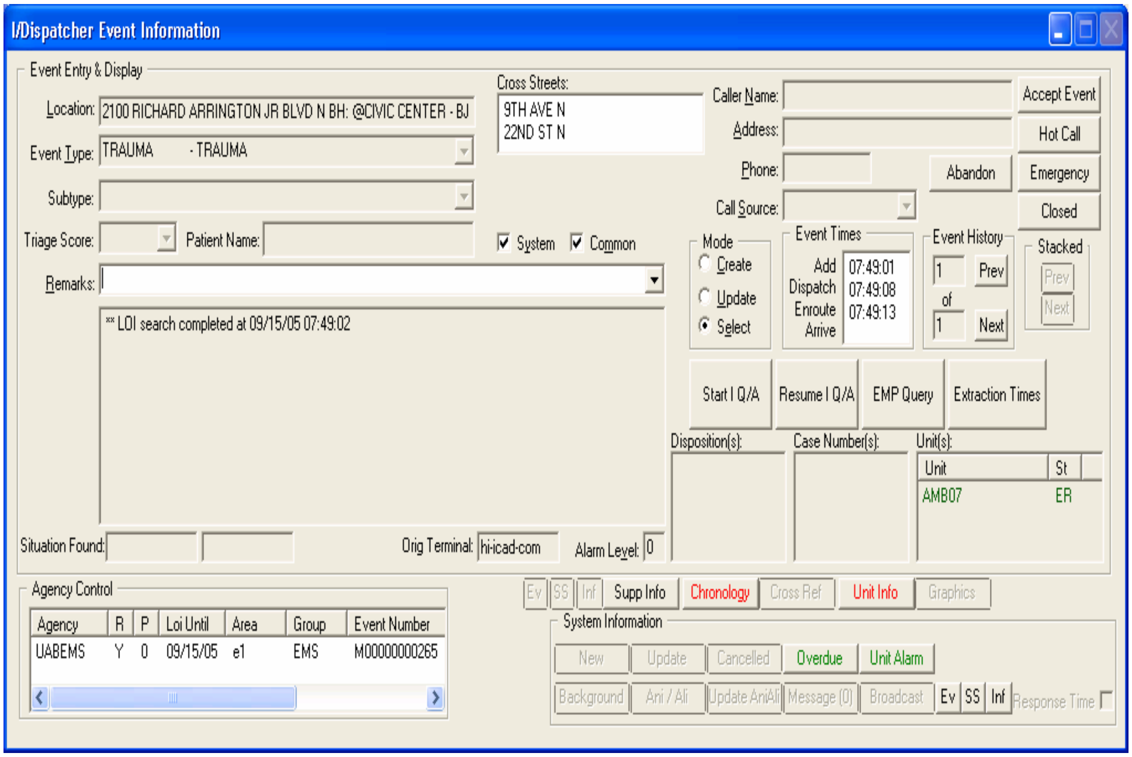
I/CAD Workstations -
The workstation consists of a specially configured Intel Processor-based computer with triple 18" flat screens. An Uninterruptible Power Supply (UPS) provides protection against power loss (seen behind the chair and processor box) in the figure to the left). One workstation, referred to as the Call Taker, will be used as the simulated call taking and medical triage (see figure to the left). Once a 911 event is created, that event is pushed to the dispatcher's workstation. The Call Taker's workstation is also functioning as a communication server for the CAD system's mobile application. The second I/CAD workstation known as the Dispatcher workstation is similarly configured but does not support some of the communications functions needed when we integrate the mobile terminals. The Dispatcher's work station will dispatch the most appropriate unit based on the caller's information and the availability of the responding units. Also, this workstation may be moved to BREMSS at a later stage. Both workstations are on the same Ethernet segment in the Learning Resource Center (LRC) suite.

Figure #2 I/CAD Screen Shot:



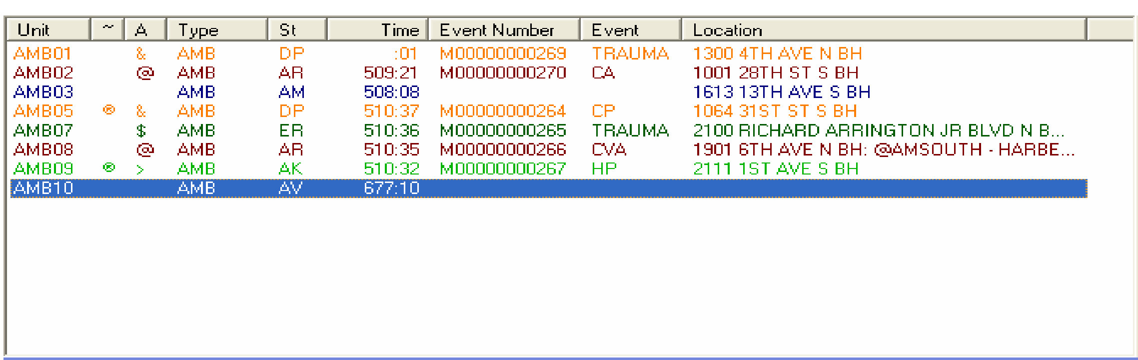
I/Call Taker – An interface to an Oracle or SQL Server database that stores information such as, addresses, incident histories, location hazard information and much more, automating the call taking process. I/Call Taker aids in the reduction of human error through on-screen forms to show operators what information needs to be recorded. By using the ANI/ALI (Automated Number Identification/Automatic Location Identifier), data from the E9-1-1 telephone database is immediately loaded into appropriate fields on the form. Each form allows for the customizing of each agencies 10-codes, abbreviated name-codes and symbols used on the map display to indicate the location of events. This allows the call taker to enter locations by specific addresses, street intersections, common place names or by aliases.

Figure #3 I/Call Taker & I/Dispatcher:



I/ Dispatcher – I/Dispatcher is the emergency-dispatching hub of I/CAD system. Using an oracle database and configuration tools, data related to the event such as address, incident history, hospital downtime, unit activity can be recorded in such a way that it is useful to the dispatcher and administrator. I/Dispatcher provides several methods for the dispatcher to recommend units. For our project we will use I/Dispatcher to identify the location of closest unit or identify special equipment needs in order to help the patient.

Figure #4 I/CAD Dispatcher Status Window:

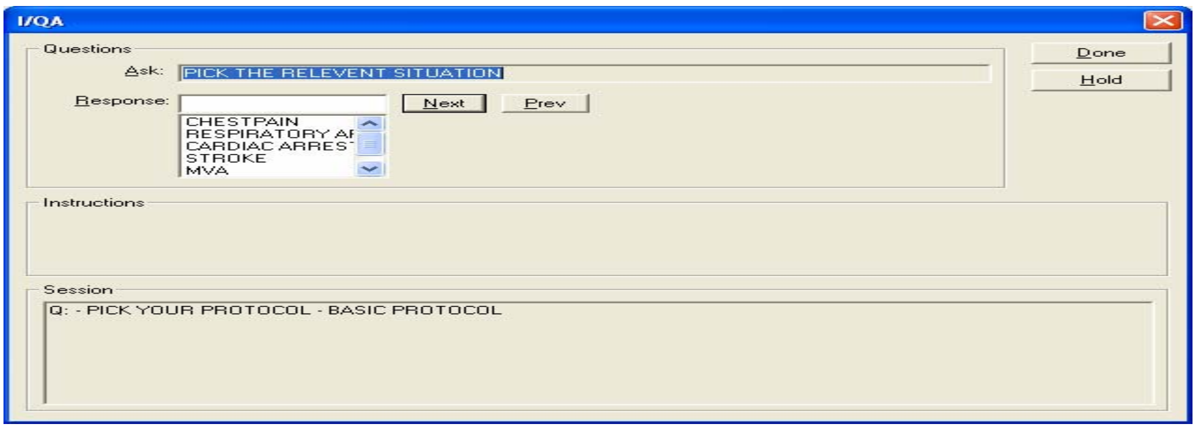


Color Codes Explanations:

- Orange – Dispatched - DP
- Red – Arrived - AR
- Blue – Available Mobile - AM
- Dark Green – Enroute - ER
- Light Green – Acknowledged - AK
- Black – Available - AV

I/Q&A – This software package supports the call taker/dispatcher function in the I/CAD system. I/Q&A allows the call taker or dispatcher to select a predefined line of questioning, depending on the customer, to enhance their ability to quickly assist the caller or make decisions regarding the disposition of the call. Each answer can have associated action, such as setting the event type or raising the priority of the selected incident. I/Q&A interfaces with the I/CAD database are real time and updates the records as information is entered. It consists of a server component, an I/Q&A builder, and a client component that integrates the answer and question into the dispatching environment.

Figure #5 – I/Q&A Protocol:



I/Net Viewer – I/Net Viewer allows personnel throughout an enterprise access to the dispatch information they need without having the specialized CAD software installed on their computers. It provides remote users access to current 911 events and allows the ability to create 911 events remotely via the I/Net Viewer web page. I/Net Viewer is based on standard intranet technology. Installation, updates and maintenance of software are accomplished from a single site making it unnecessary to maintain software on remote computers. Net Viewer is a window into the I/CAD but it also allows the user to accomplish a host of other tasks. Security is maintained at both the application and operating system levels. The system uses 128-bit, dual key encrypted Internet security.

Figure #6 – I/Net Viewer Screen Shot:

PATIENT PERSONAL DATA

Name	Gender	DOB	ID Type	ID Number	Address	City	State
Tim Smith	M	4/21/1980	SSN	345-74-7835	297 Ridge Rd	Hoover	AL

CURRENT MEDS

Stop Date	Repeats	Code	Title	Dose	Freq	Medication
		19789-7	Medications			Finastride

VITALS

CapRefill	Diastolic BP	Glucose	Left Pupil	P02	Pulse	ReadingDate	ReadingTime	Right Pupil	Skin Color	Skin Cond	Systolic BP	Temperature	Mental Status
<=2s	94		Sluggish		122	10/5/2005	9:37 AM	Reactive	Pale	Cool	142	98	Alert
<=2s	869		Sluggish		128	10/5/2005	9:42 AM	Reactive	Normal	Dry	122		Verbal

TREATMENTS

Authorized By	Crew	Dosage	Medi-cation	Units	Response	Route	Treatment Date	Treatment Time
On-Line Direction			Normal Saline	LITERS	Unchanged	IV	10/5/2005	9:40 AM

PROCEDURES

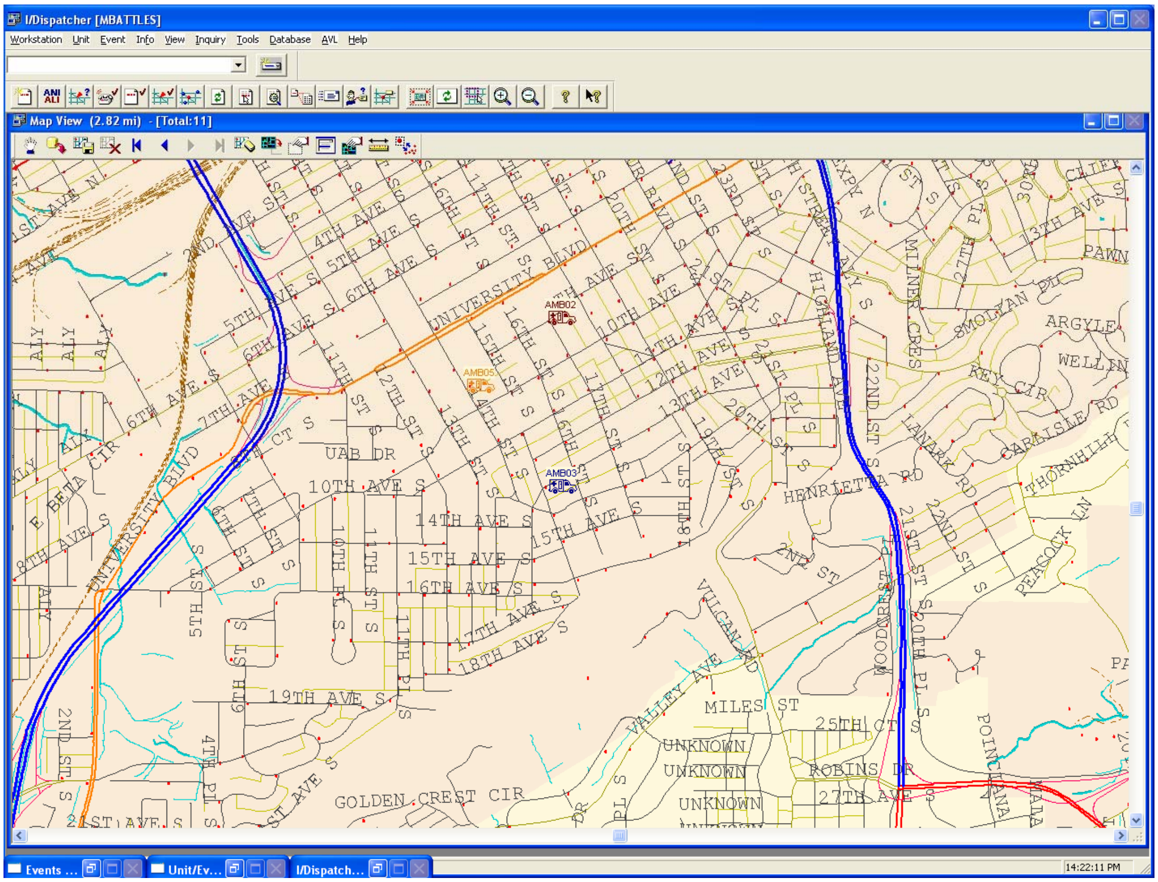
AuthorizedBy	Crew	Attempts	Procedure	Response	TreatmentDate	TreatmentTime
Protocol	Peter	1	96.010 Airway-Nasal	Improved	10/5/2005	9:39 AM

RUN NARRATIVE

Narrative Text
10/5/2005 11:59:41 AM -- Responded to a motor vehicle collision at Algonquin intersection. Upon arrival, found approximately 25-yeard old male lying left lateral recumbent across center of vehicle. Patient appeared to be the unrestrained passenger of compact vehicle that received head-on impact from full-size pick-up travelling at approximately 45 mph. Airbags were deployed. Initial assessment showed patient responsive to verbal stimuli but unaware of surroundings and unable to recall incident. Obvious bleeding noted to facial region with no apparent compromise to airway. Skin warm and dry. Rapidly extricated patient onto spine board and immobilized with straps c-collar, and head blocks and initiated high-concentration O2 and rapid transport.

I/MAP – The maps of this suite are fully- integrated intelligent maps. It can display various features related to efficient evacuation of patient such as location of emergency facilities, defibrillators, highways and streets, fire hydrants, congestion on road etc. These maps are 'smart' enough to include extensive database records. The dispatcher can query the system by simply pointing and clicking on symbols on the map. Our dispatcher can quickly find and route units by the shortest time, shortest distance, fewest turns, intersections and minimum risk involved by pending and selecting various events

Figure #7 - I/Map Screen Shot:

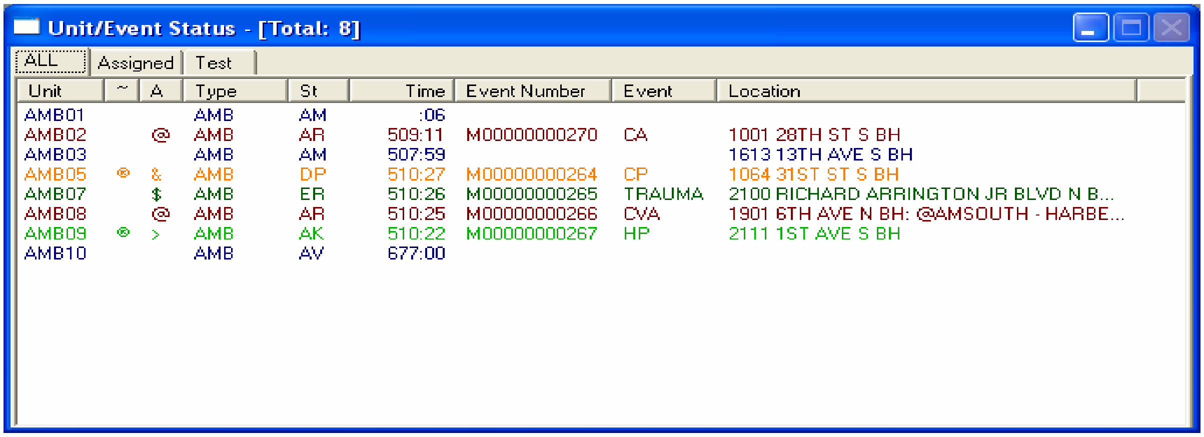


I/Informer - Is a software module designed to work seamlessly with IPS (Intergraph Public Safety) and non-IPS provided databases allowing users to quickly retrieve pertinent information related to vehicles, persons, and property. The I/Informer modules are an optional application comprised of server and client components. The server component runs on the communications server and consists of a link control process that typically connects to external systems via TCP/IP. The server routes queries and responses between the clients and the external systems. External systems commonly supported include state and national information databases. The client components consist of a form-based graphical user interface that works with I/Calltaker, I/Dispatcher, and I/MobileTC clients. Configurable HTML forms, which are used to execute transactions against external systems, are provided. The base product includes five unique transactions. Additional transactions can be developed via additional services, or the utility company can edit the delivered HTML.

Figure #8 – Emergency Provider Database Lookup:

I/System Status Monitor (I/SSM) - System Status Monitor works against a coverage plan. The coverage plans consists of an area and the units that are to cover that area, for an agency. Thus, a plan applies to a dispatch group. Each dispatch group may have one or more such plans. SSM is a tool that helps to plan and design the use of resources so as to achieve the best coverage, thereby maximizing effectiveness. With SSM, the dispatcher can visualize resources utilization, planned coverage, and take the necessary steps to change resource location, improved [planned coverage, and improve the ability to respond to possible calls. The monitor component of SSM runs on the dispatcher's workstation and determines whether the location of valuable resources meets the requirements of the activation plan or plans, as predefined. Reporting will be preformed using the recommended I/MARS product provides the analysis by which active plans are developed. The server process monitors activity and resources, notifying dispatchers and supervisors when resources fall below predefined levels. A predefined level of resources, indicated in the plan, identifies station locations of additional resources that can be used when fall below an established level. Using these plans can allow dispatchers and supervisors the ability to request that additional units be "moved up". This requires moving units from one location to another to sustain baseline resource levels. I/SSM assist dispatchers and supervisors by calculating and recommending the optimum units to be "moved up". There are three components of the SSM within a system; the monitor, analyzing incident data (for incorporating into plans), and developing/entering plans.

Figure #9 – Unit/Event Status Window:



I/Mobile - A software module that provides capabilities for voiceless dispatch, status updates, messaging, and queries to a variety of systems. I/Mobile also interfaces with automatic vehicle location (AVL) hardware and provides extensive map capabilities. Intergraph's I/Mobile solution, allow mobile data transmitted to a hand held PDA or tablet computer. EMS field personnel can send and receive text messages, add input to the details of an incident, give GPS updates, access local and national police databases. The information can be transmitted one of three ways; In-vehicle devices, handheld devices, or by radio terminal systems.

Figure # 10a – I/Mobile Window:

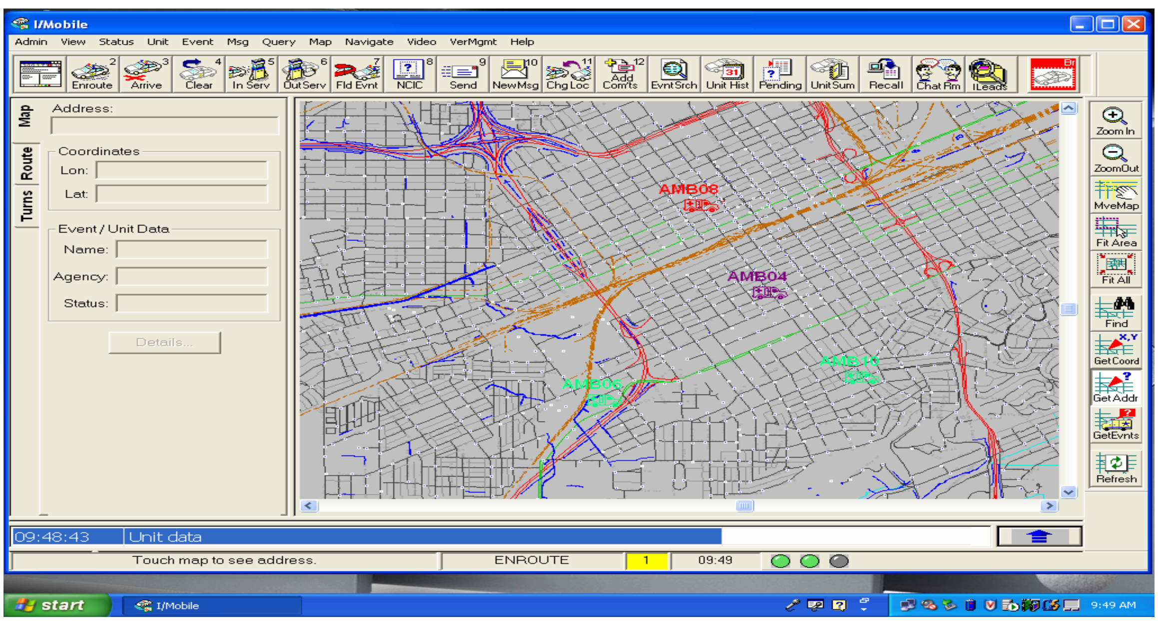
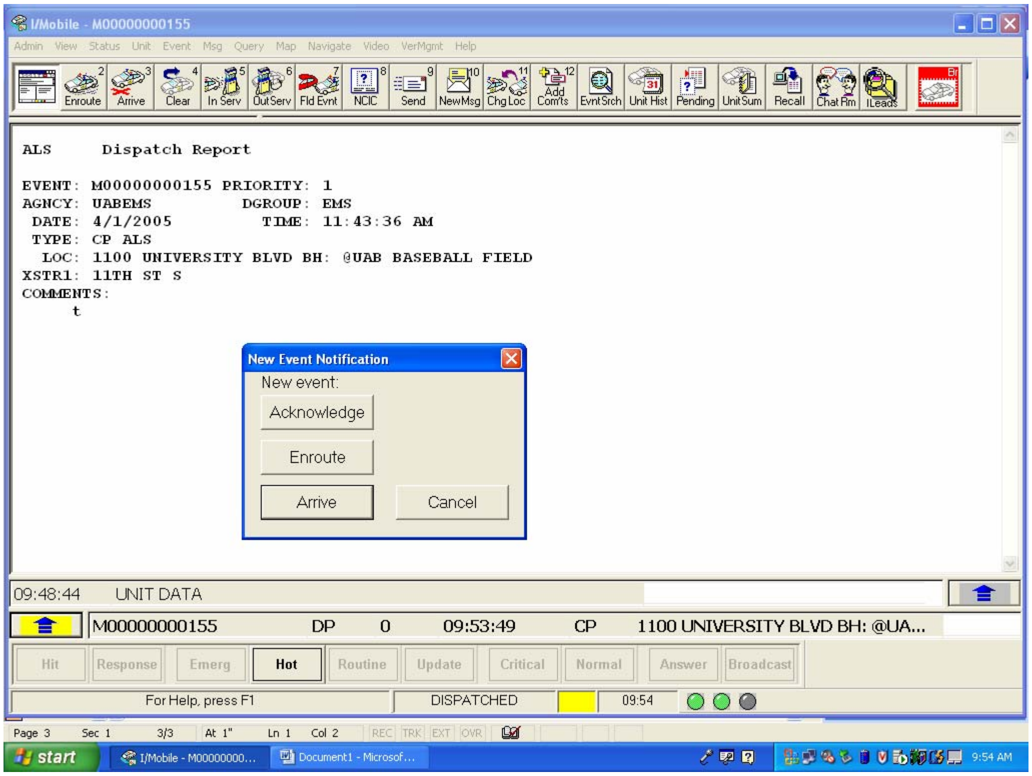
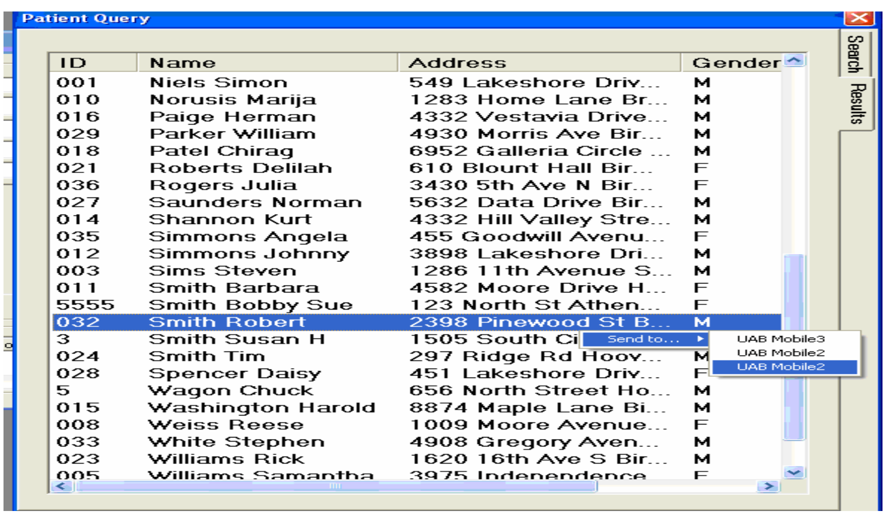


Figure # 10b – I/Mobile Window:



I/Mobile Data Terminal (MDT) - The native interface providing Mobile Data Computer clients the ability to query the I/CAD system for status updates, field event creations, event updates, text messaging, and a host of other outbound reports. I/MDT, the server-based interface for in-service mobile computing functionality, routes data to a variety of other wireless infrastructures, including radio, CDPD, circuit-switched cellular systems, satellites, and wireless local area networks (LANs).

Figure #11 – Emergency Provider Database to MDT:



I/Intergraph/Management Analysis and Reporting System (MARS) - Supports the analyzing of data from the I/CAD and RMS databases. Also supports the tactical operations of the Dispatching and Records Management organizations by providing a tool for easily analyzing and presenting strategic information. I/MARS will analyze and display strategic information in the form of charts, graphs, reports or maps. The displays can then be used for performance measurement, resource planning, center management and 911 event analysis.

Geographic Information System (GIS) Maps for BREMSS Region

Mapping

The I/CAD map is provided primarily to enhance situational awareness. Command buttons on the map screen allow the user to control the appearance of the map display. Users can zoom-in on views, window certain areas, attach related graphic files to expand their informational base, turn on and off different map layers to control the amount of data shown, and query the database about map symbols. The map view is also used to display routing information, such as the route a particular unit should take to an event, as well as suggestion of alternate routes. It can also display routes from the scene to hospitals or other facilities. In addition, symbols can be used to indicate items like the location of AED devices throughout the region or even within a particular building by using the building plan. The map can also be used to measure distances, display bit map images or other critical data. In a chemical, biological, or radiological accident, plume models generated at the emergency operations center level could be plotted automatically on the map enabling first responders to protect themselves in the event of a disaster. In this type of event, the map could also be used to show areas where there is a high probability that patients from these areas could potentially be contaminated or exposed.

The original NLM contract listed the 6 county BREMSS region map as a deliverable of the project. The current map only incorporates the City of Birmingham. UAB will add Blount, Chilton, Jefferson, St. Clair, Shelby, and Walker counties. Intergraph will produce a six county map, if UAB can provide the map data in a readable format. The basic map data will be obtained by UAB and then merged into one common map. To be cost effective, the individual county maps acquired by the project team will be integrated as one BREMSS coverage map prior to the incorporation into the I/CAD software.

Asset Allocation Data Elements for Map

The group reviewed a list of data elements UAB wants to incorporate into the map. These items are all possible. The effort will take considerable man-hours. The best strategy will be for Intergraph to provide UAB with the tools and training to add these elements. It was agreed that the 6 county region was too big an area for testing. For purposes of the study, these data elements will be limited to the Birmingham City limits. If it is found that the city limits still pose to big a region, the scope will be further limited.

Static Icons/Information (List of locations to be obtained by UAB)

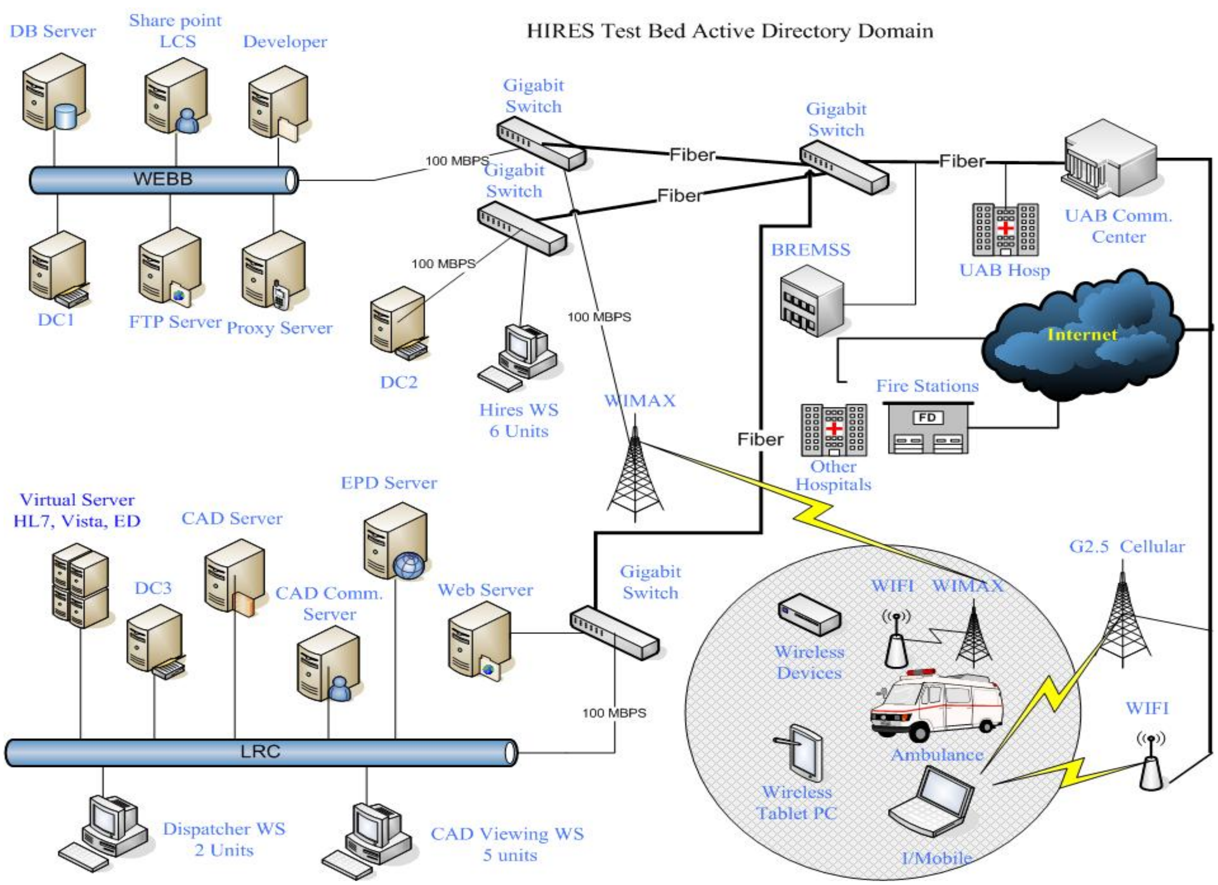
- Hospitals monitored by BREMSS
- Area clinics that could be used in a disaster scenario
- State Health Department and Department of Public Health facilities

- EMS/Fire Station Locations (Special addresses are in available in Birmingham Fire data set. There are no symbols.)
- Defibrillators/AED's
- EMA Office Locations
- BREMSS/TCC (two locations)
- 911 Call Centers (map not be easily obtainable)
- Police Departments

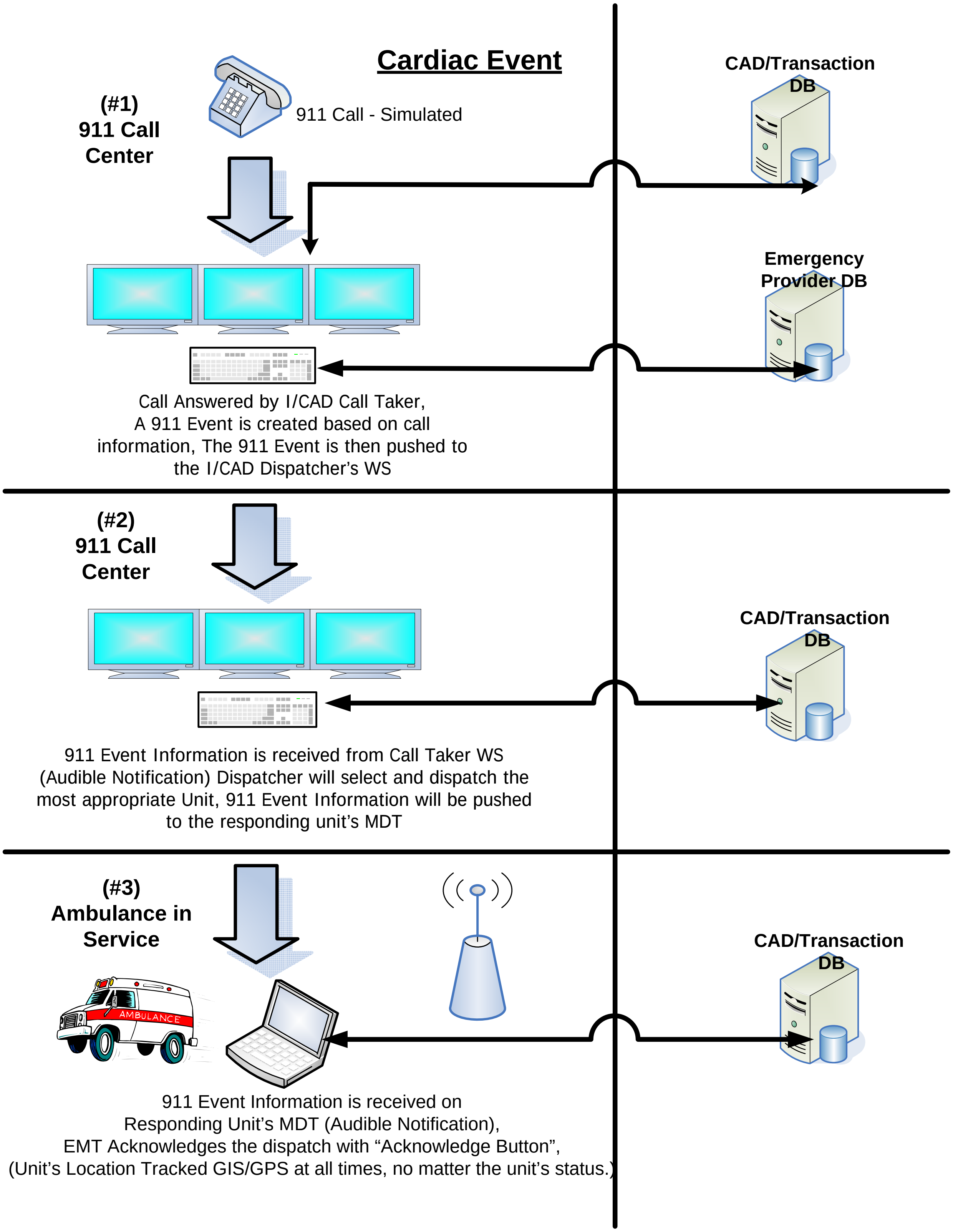
Dynamic (Icons/Information)

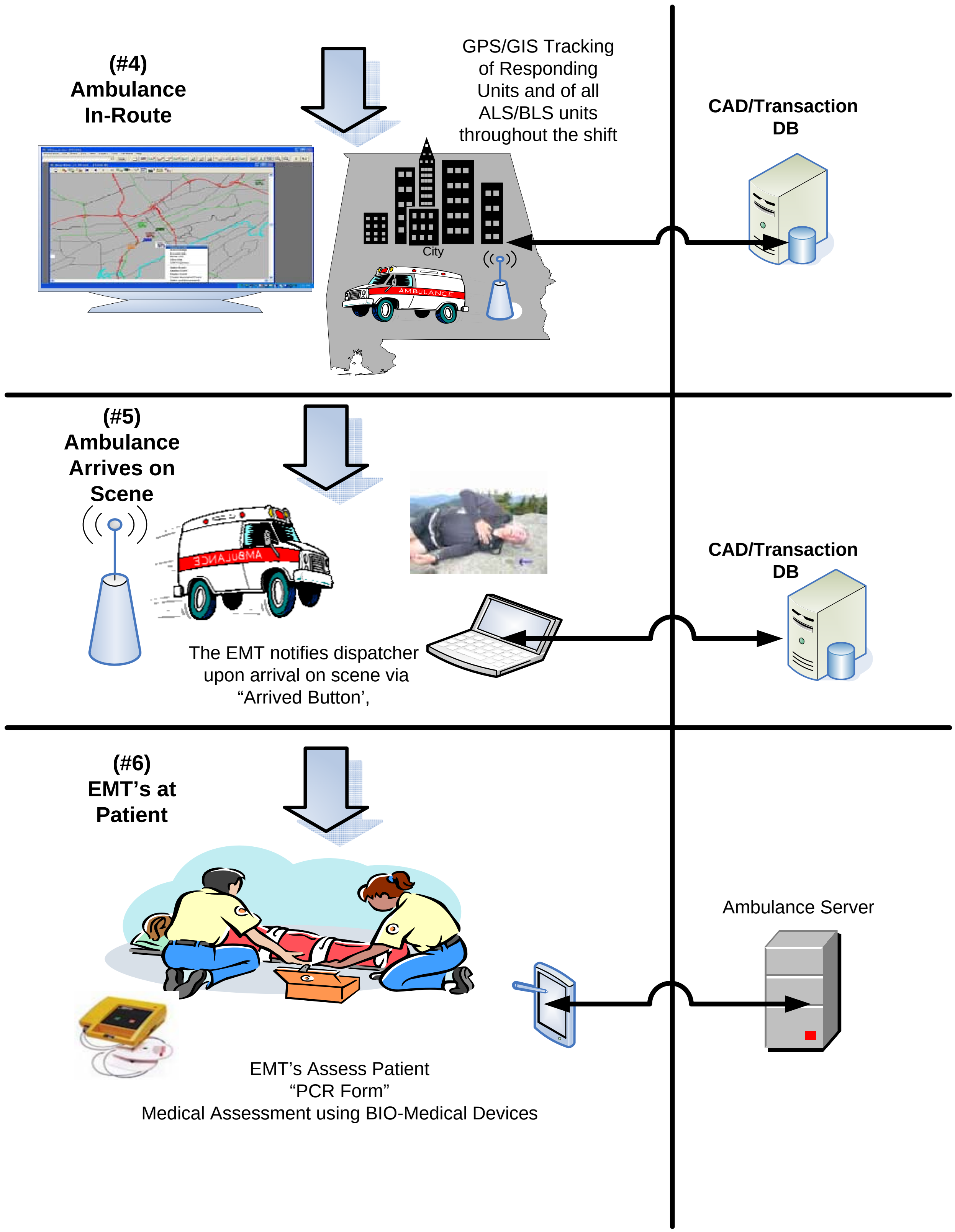
- Ambulances (Need to import Birmingham Fire Vehicle and Unit Definitions. Would use separate icon for ALS, BLS, and 1st Responder if applicable.)
- Mobile Command Centers (Would need units in CAD Data set and special Icon) Defibrillators located in Police Cars (done through cad and not the map related)
- WiFi Hotspots?? (Concept would be to show where units could go for a high-speed connection. This may not prove to be practical.)

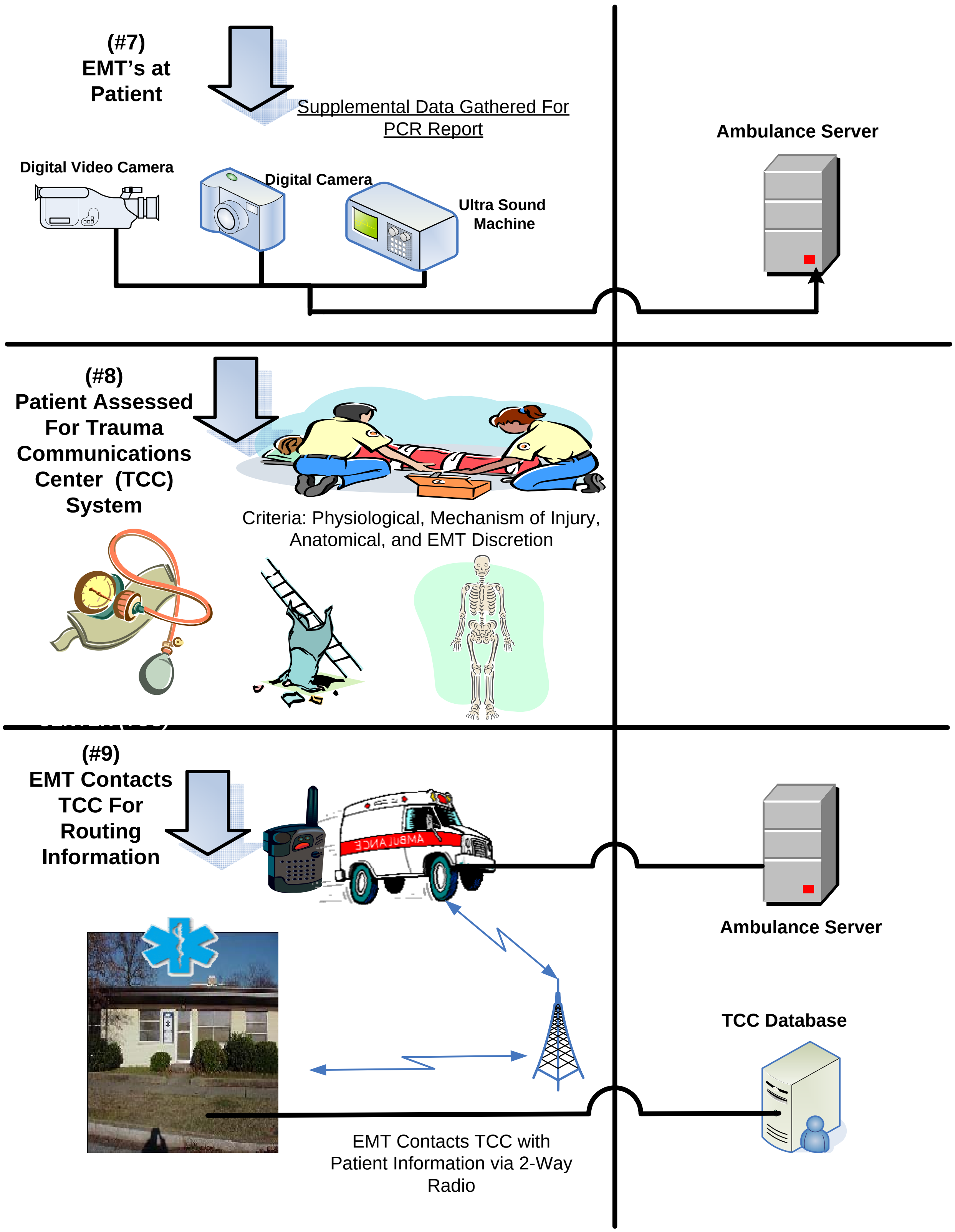
Figure #12 - Test Bed Network:

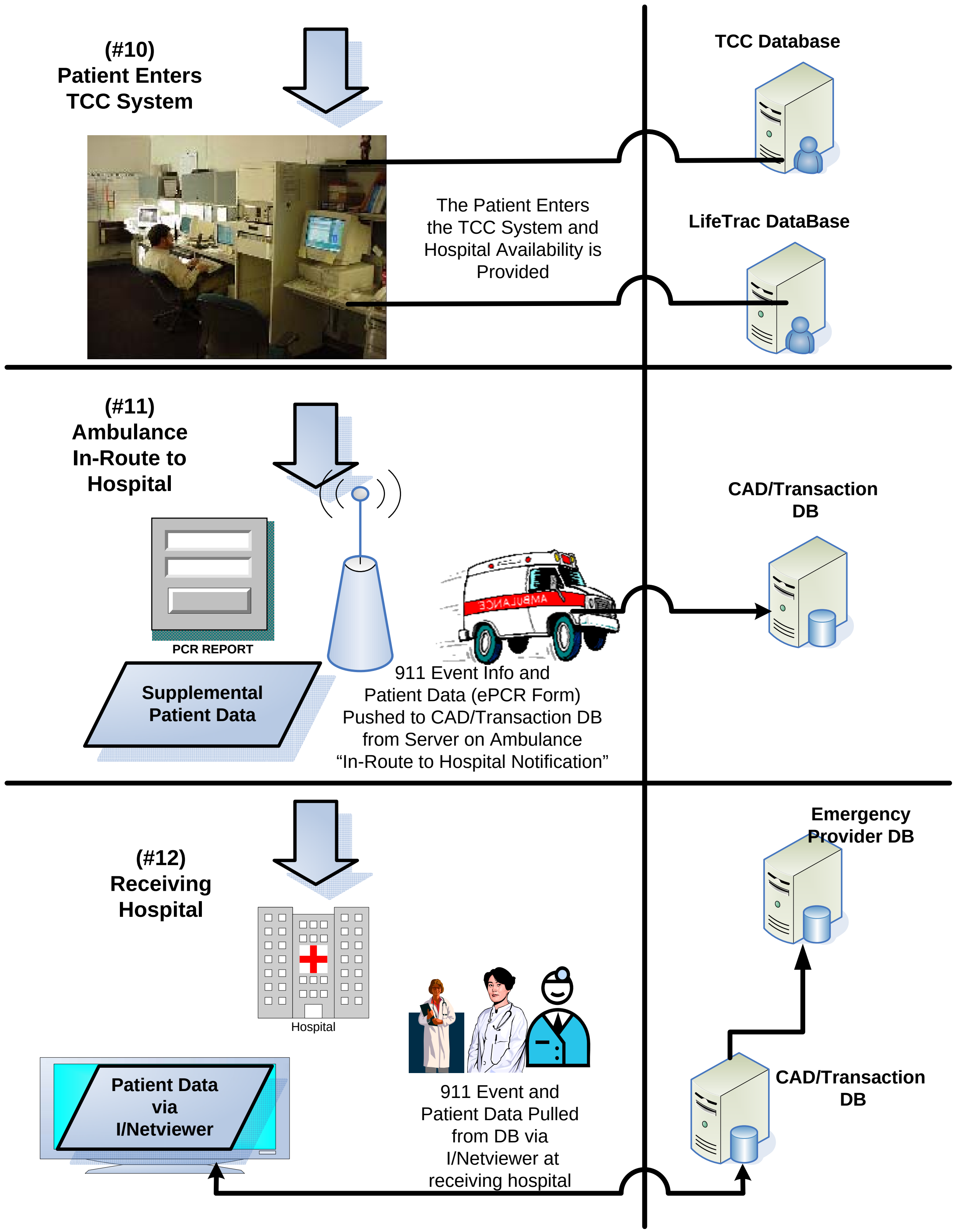


Scenario #1 Cardiac Event




(#4)
Ambulance
In-Route
GPS/GIS Tracking
of Responding
Units and of all
ALS/BLS units
throughout the shift
City
CAD/Transaction
DB
(#5)
Ambulance
Arrives on
Scene
The EMT notifies dispatcher
upon arrival on scene via
"Arrived Button',
CAD/Transaction
DB
(#6)
EMT's at
Patient
Ambulance Server
EMT's Assess Patient
"PCR Form"
Medical Assessment using BIO-Medical Devices


(#7)
EMT's at
Patient
Supplemental Data Gathered For
PCR Report
Ambulance Server
Digital Video Camera
Digital Camera
Ultra Sound
Machine
(#8)
Patient Assessed
For Trauma
Communications
Center (TCC)
System
Criteria: Physiological, Mechanism of Injury,
Anatomical, and EMT Discretion
(#9)
EMT Contacts
TCC For
Routing
Information
AMBULANCE
Ambulance Server
TCC Database
EMT Contacts TCC with
Patient Information via 2-Way
Radio


(#10)
Patient Enters
TCC System
TCC Database
The Patient Enters
the TCC System and
Hospital Availability is
Provided
LifeTrac DataBase
(#11)
Ambulance
In-Route to
Hospital
CAD/Transaction
DB
PCR REPORT
Supplemental
Patient Data
911 Event Info and
Patient Data (ePCR Form)
Pushed to CAD/Transaction DB
from Server on Ambulance
"In-Route to Hospital Notification"
(#12)
Receiving
Hospital
Emergency
Provider DB
Hospital
Patient Data
via
I/Netviewer
911 Event and
Patient Data Pulled
from DB via
I/Netviewer at
receiving hospital
CAD/Transaction
DB

Project #2 "Next Generation Emergency Medical Responder"

The "Next Generation Emergency Responder" project has developed a test bed infrastructure for the pre-hospital EMS environment starting with the 9-1-1 emergency medical call to the delivery of the patient to appropriate Emergency Department (ED) where treatment can immediately be initiated. This test bed allows the study of technical problems in the EMS environment and the implementation and evaluation of technical solutions. One of the problems is the collection and transmission of medical information about the patient from the field before the patient's arrival to the ED; including the transmission of all available information about the patient during a run. In order to study the usability and technical feasibility of collecting and sending information during a run an electronic patient care report (ePCR) has been designed. This system is able to receive patient information from the 9-1-1 dispatcher and acquire accurate clinical data in the field, and transmit this data to the ED before the patient arrives. The UAB core team developed a field testing plan for Project #2 outlining the goals and objectives. In the field testing, simulated EMS personnel have used the handheld systems, assessing the hardware features and usability of these devices in field conditions. The feedback provided by the EMS personnel presented us an insight into the features needed to maximize the use and utility of the system for real world implementations.

Goals

- Facilitate patient care through expedient and efficient collection and exchange of emergency patient information between pre-hospital care personnel and physicians at the receiving facility (i.e., Hospital)
- Improve collection of data in the field in terms of accuracy, timeliness and efficiency
- Enhanced field triage due to inflow of information from EMS database

Objectives

- The utility of handheld device and opinion on touch screen, battery life, durability, weight etc.
    - Method: We will request EMT's to compare our equipment with existing equipments for their usability in field conditions.
- The layout and format of graphical user interface
    - Method: We will test and report the applications on various matrixes such as
        1. Navigational ability
        2. Speed responsiveness
        3. Use of controls such as Menu bar, Pull down menu, Cascading menu, Pop-up menu, Push buttons etc.
        4. Appropriate use of Dialogue Boxes such document window, application window etc.
- Communication system interface and functionality
    - Methods: Under investigation at this point
- Data input study for select case (e.g. chest pain patients) and comparison with earlier cases with old techniques.
    - Methods: This study shall study clinical data collection for quantitative attributes; such as ease of use, speed and quality of data collected as well as qualitative attributes such as less error, better triage etc.

- Data transmission speeds over different communication technologies
    - Methods: Speed of connection for same data files using different communication technologies.
- Download time from EMS database
    - Methods: Download time for data files using different communication technologies.
- Effect of EMS database information on field triage decisions.
    - Methods: Standardized simulated patients to be triaged by two groups of EMT's; with and without EMS database support.
- Upload of vital signs to local server and its subsequent transfer to ED
    - Methods: Using Bluetooth or RF for data collection from sensors and their storage in ambulance unit and subsequent transfer to Emergency department and database.

The core team also developed a field plan to test instant messaging, voice and video communication for the effectiveness and use in the medical environment. The instant messaging (IM) domain needs to be evaluated before it can be successfully implemented into the system. There are certain parameters which need to be tested; they are divided into two basic groups:

- Technical parameters to test the feasibility and quality of service for real time IM messaging. Test of latency, quality of service when voice and video are included and the system behaviors when the user is roaming consistently.
- The acceptability, use and benefits of the service in various medical scenarios.

Problem Scope

The amount of information collected in the fields varies among EMS agency and from state to state. In order to limit the scope of the problem the ePCR has been designed to collect a subset of the NEMSIS data elements required by the state. Due to the complexity of EMS, just trauma, cardio and stroke cases have been considered to test the usability of the system.

Electronic Patient System (ePatient)

The entire system to manage the PCR information flow is known as **ePatient**. The first iteration of the ePatient System was developed in collaboration with Intergraph Corporation. The test bed uses Intergraph's Computer Aided Dispatch (9-1-1 CAD) system as the main dispatch system. This 9-1-1 medical dispatch system (I/Dispatch) was enhanced with optimized dispatch algorithms for acute cardiac and trauma incidents make use of critical patient data (if available electronically) and push this data with the new event data obtained by the dispatcher to the ePCR before the EMS provider arrived at the patient. The ePCR was also enhanced to communicate with the central ePatient database using several communication methods such as Verizon's CDMA EV-DO (a 2.5G cell phone technology), Wi-Max (IEEE 802.16), and Wi-FI (IEEE 802.11). Essentially, the test bed gives us the ability to study the entire pre-hospital care process from the moment the 9-1-1 call is generated to the moment the patient is delivered to the hospital and handed over to the ED team. The EPatient System encompasses the following parts:

- The **ePCR** is the main GUI employed by the EMS providers to collect clinical information in the field about the patient and store in the local DB.
- The **eMonitor** is a component that is always running in the background and is used to send/receive information to/from the ambulance and the main database independently of

the state of the network. If the network is not available for any reason it just keeps waiting until one of the three network transports is available. The network itself will choose the fastest transport if more than one are available.

- The **ePatientDB** is the Microsoft SQL database used to collect the patient information. A local copy of the database is carried by the mobile devices but limited to information for the current run. The synchronization of the local copy with the central database occurs when there is network connectivity.
- The **CADClient** is a GUI used to search the ePatientDB for information about the patient from previous runs that can be sent to the ePCR in advance by the 9-1-1 medical dispatcher from the dispatch station.
- The **EPWebService** is a web service used to show summary information about the patient inside the I/Netviewer system. I/Netviewer is a web interface of the Intergraph CAD system.
- The **ePatientService** is a component used to relate the information collected with the ePCR system with the information collected by the Intergraph CAD system. In the field the CAD system uses I/Mobile GUI to collect and send information about the event.
- The **ePatientWeb** is a web server which allows the display of relevant information in a browser using the EPWebService. This is used to exchange information with other entities without the need for the other entity to have a web services infrastructure.

The I/Mobile is a part of the I/Dispatch System used to monitor and send the GPS coordinates of the ambulance and collect information about the event. I/Mobile also receives and sends status information back and forth to the dispatch system from the field. The idea is to use I/Mobile and ePatient together to monitor and manage EMS events, including where the necessary clinical resources are available to treat a patient and provide patient information to the staff in the ED before the patient arrives. Figure #13, shows the main data flow among the different components of the ePatient System. Each color denotes where the application is running at the moment of interaction in a single run.

Figure #13 ePatient Data Flow:

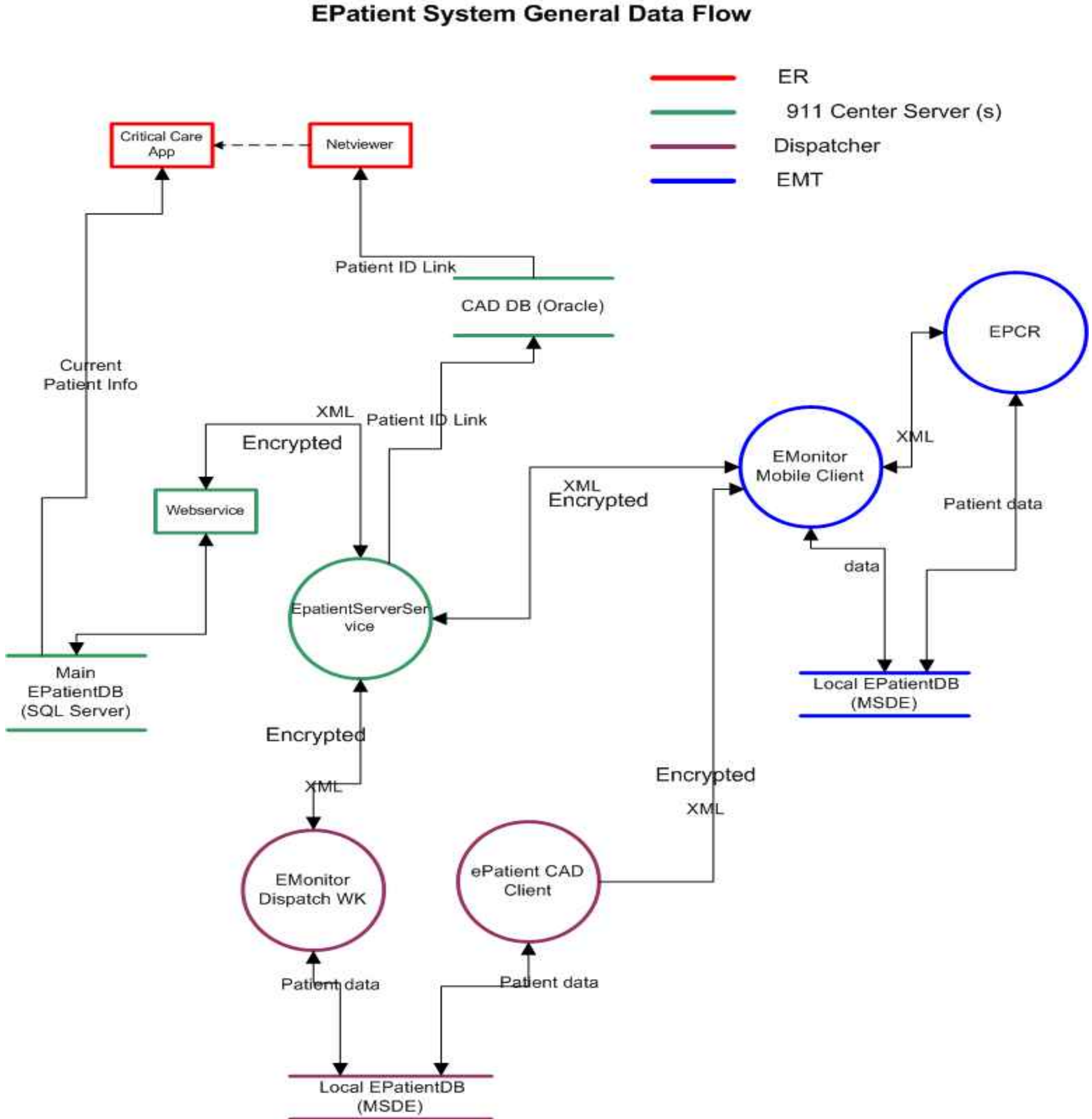
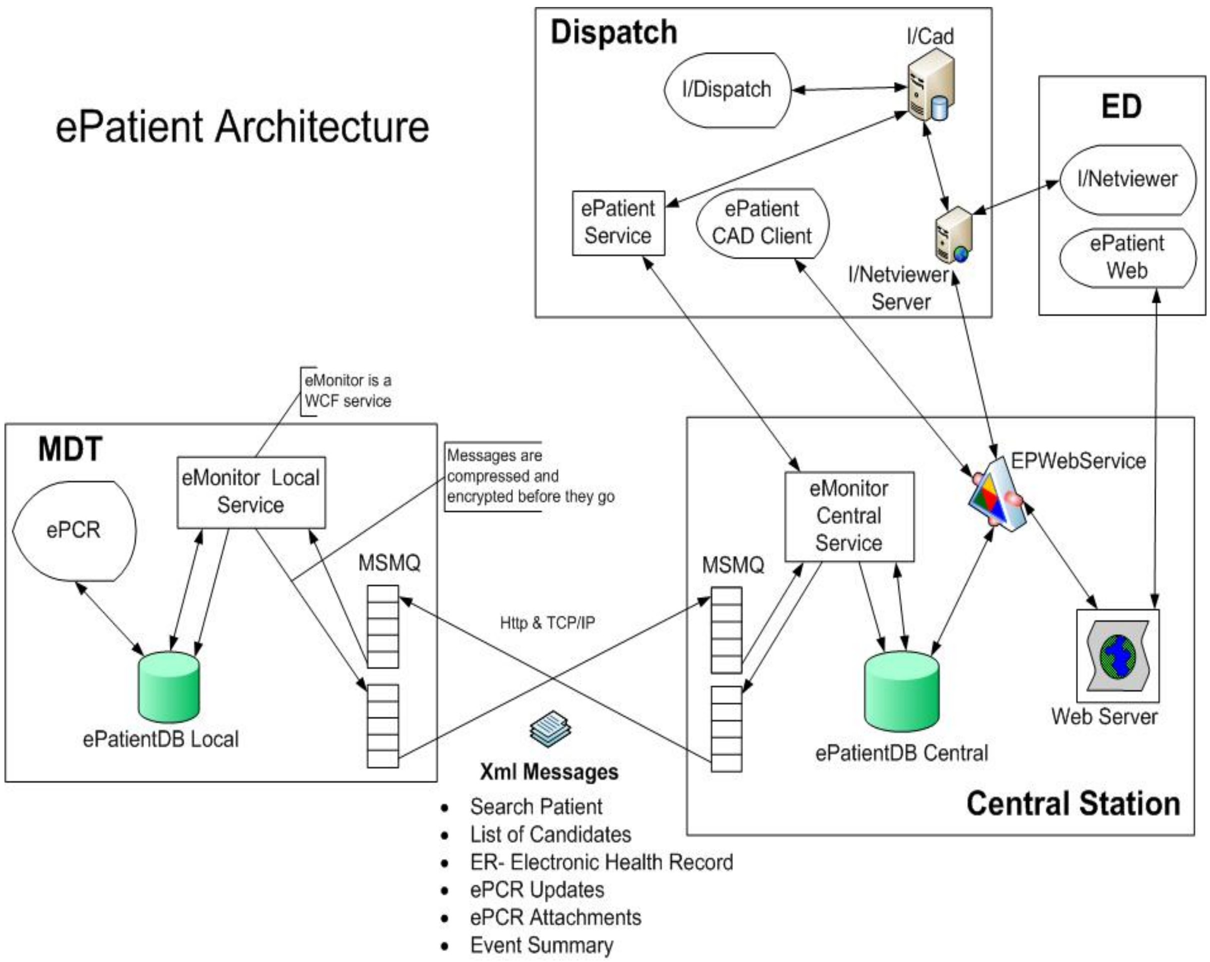


Figure #14 shows the whole architecture for the second iteration of the application. The main change was the use of Windows Communications Foundation (WCF) to build the eMonitor system. Using WCF allows changes to the transport mechanism for the messages. For the message exchange between the EMT and the Central Station the system uses Microsoft Message Queue (MSMQ) as the transport mechanisms. This allows for a queue to queue communication using http and TCP/IP that can be interrupted in any moment and have a way to recover. There is a special ping message that is used to check for the status of the connection.

Figure #14 ePatient Architecture:

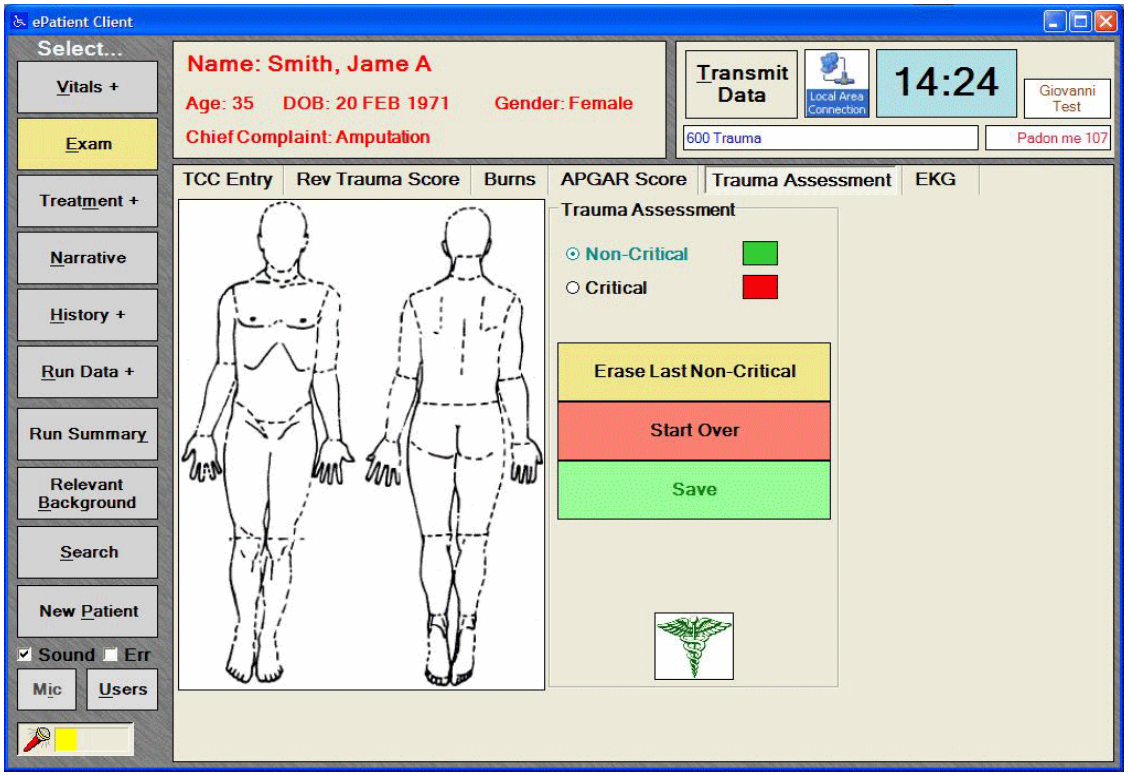


ePCR Architecture

Giovanni Mazza, MSHI, Network Administrator and Lead Developer

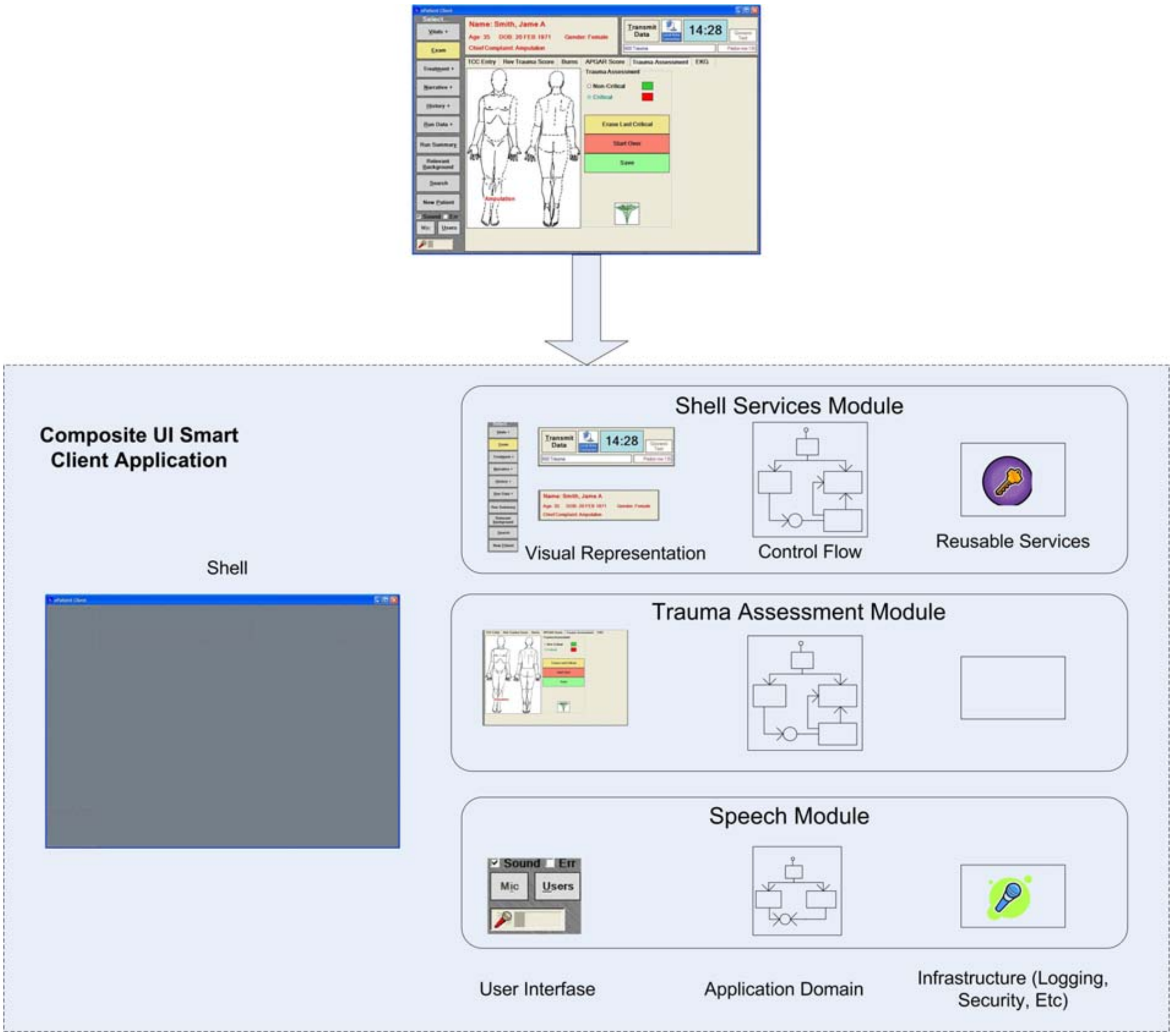
The ePCR is the GUI portion of the EPatient system implemented on the mobile units (Tablet PCs) and used by Emergency Medical Technicians (EMTs) in the field. Figure #15 shows a snapshot of the ePCR. During the first iteration we used a classical Windows Forms Client/Server Architecture using C# with a local Microsoft SQL Database. In classical windows form design, the main form was loaded with code and the different portions of the ePCR were loaded in different Windows Controls that are loaded into the main form at run-time when required. This architecture provided flexibility but the business logic and the presentation logic were intertwined inside the forms code; thus, every modification and event manipulation required considerable code modifications in the main form. Initially, we thought these limitations were not important but when we received feedback from EMTs about feature requests (e.g., a speech recognition feature), the limitations of our architecture emerged and the need for a more flexible architecture became imperative.

Figure #15 ePCR User Interface:



For the second iteration of EPatient, we adopted a new architectural model proposed by the Microsoft Patterns & Practices team to develop smart client software. This new model is called Composite User Interface Application Block (CAB). This model allows an application to be based on the concept of modules or plug-ins that are hosted in a main Windows Form called a "shell." These plug-ins enable developers to build components that hide user interface complexity from the business logic development and facilitates development using patterns for loose coupling between modules. Each module acts as a separate piece of software that also can be deployed separately and integrated at run-time into the main shell through XML configuration files. Figure #16 (based on the CAB model as shown in [1]) shows a general overview of the modularization of the main subsystems that constitutes the ePatient CAB implementation. Each module as well as the shell could be developed by different teams as long as the interfaces and common models are kept. The modules could be deployed separately and loaded according to need. For instance the speech recognition could be loaded when needed and deployed separately from the application.

Figure #16 - Overview of the Composite UI Application Block:



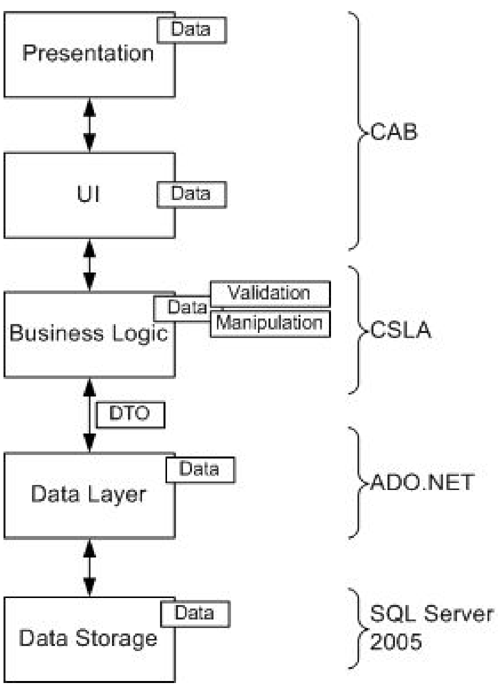
The separation of GUI logic from business logic is not a novel idea, but in CAB the GUI itself is composed at run-time using different modules that are independent. Each GUI module has a main event-driven infrastructure that facilitates interaction among modules to share data represented within business objects that abstract all the data access from the application.

For the creation of a new business logic layer, another framework has been chosen. This framework is called CSLA (Component-based, Scalable, Logical Architecture), which assists in creating movable business objects that can be hosted on a central server or can be moved to a remote client. A CSLA business object contains a representation of the data and all the validation required by the business rules. Each business object has an independent data layer that contains the logic to preserve the object's state into the database. The data layer and the business layer can be integrated into the same object or be separated in different objects across address spaces. For the EPCR, the data layer is a separate business object and exchanges information with the data layer using DTO (Data Transport Objects), which are simple objects that represent data. The data layers use ADO.Net Datasets to preserve the information into the local database.

All of the overhead associated with this process (i.e., user interface interaction, validation of the business object, and movement of information to the data layer) allows for a more flexible and maintainable code but imposes a considerable amount of repetitive coding to create all the mapping. Coding is required in the following modules: from the ADO.Net Datasets to the DTOs in the data layer and later on from the business objects and the DTOs and finally the UI fields and the business object fields. To create all the mapping, the use of modeling tools makes the process straightforward, providing documentation as well as giving a graphical representation of the relation among the objects.

Figure 17 shows the architecture of the system using the model proposed by Lhotka [2]. Notice that all the business rule validations are delegated to the business objects and non-validation and manipulation are done in the other layers. DTOs are used to transfer data between the Data Layer and the Business Logic. Physically, these layers can be distributed in the network on different servers or reside on the same machine. CSLA allows streamlining the process by hiding the complexity of separating Business Logic from the Data Layer using multiple mechanisms of communication that are configurable at run-time via XML files. It is possible to use windows remoting, web services and even the new Window Communication Foundations (WCF) to move the business objects across the network so that the UI and presentation layer can use all the validation and manipulation logic locally.

Figure #17 - Architecture for the ePCR:



The last modification to the architecture from the previous version was the incorporation of the WCF as the main vehicle to move data across the network for the EMonitor portion of the EPatient system. The new version specifies services at both ends of the network to subscribe, notify and move XML messages based on the NEMSIS format to update the EPCR and query for data to the central database. WCF allows changing the mechanism of transport dynamically at run-time via XML configuration without modifying the server.

Speech Recognition

Background and Objectives

Given the limited time available in the field to Emergency Medical Technicians (EMTs), the use of an electronic form to collect patient information is difficult. In this “hands-busy” environment speech-based data entry is desirable. There are two speech recognition techniques for data entry, dictation and command & control (C&C). C&C is known to be more accurate for recognizing limited vocabularies than dictation.

The objective of this study was to use speech-enabled C&C features to improve the data entry capabilities of EMTs using our electronic Patient Care Report (ePCR) and to evaluate its feasibility**.**

Methodology

In cooperation with Intergraph Corporation we developed an ePCR GUI based on the Alabama Patient Care Report form. Standards such as the NEMSIS (National EMS Information system) NHTSA (National Highway Traffic Safety Administration) dataset (V2.2) and the HL7 CDA (V3) data model have been used to represent the data elements. The ePCR GUI uses a “finger touch” paradigm and is enhanced by C&C voice commands, this voice enhanced version is called **vePCR**.

The main tools are C#-based Windows forms using a client-server architecture consisting of a local MSDE database linked asynchronously with a central Microsoft SQL Server 2000. Dragon Naturally Speaking (V8.1) is used as the main speech recognition engine. We create voice commands that are activated and deactivated according to user context by programming the speech engine using Dragon’s Software Development Kit (SDK).

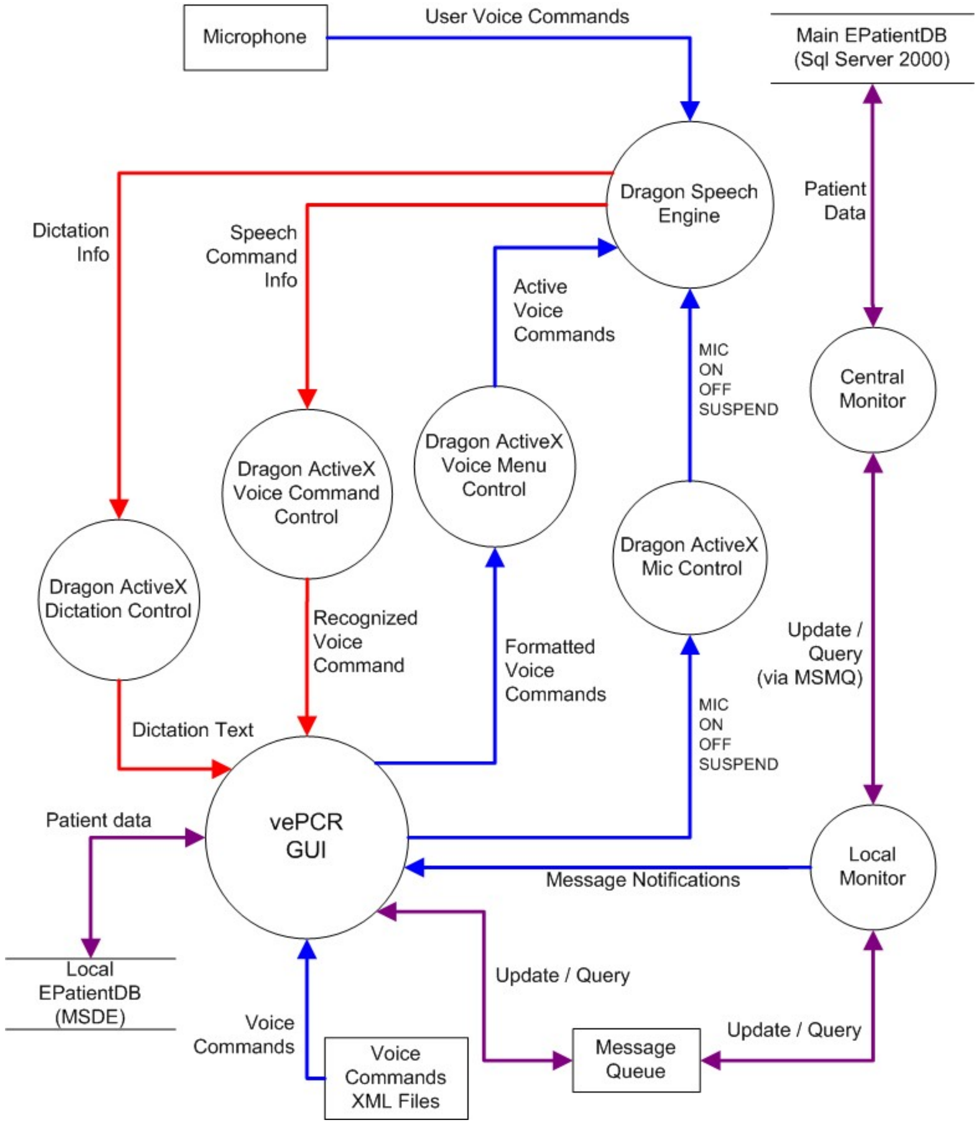
EMTs can use this vePCR to record medical information. Currently, we limit data input to structured data as shown in Table 1. We developed six clinical cases to test these commands in cardiac, trauma, and stroke scenarios (see Table 2 for stroke). The main architecture of the system is shown in Figure #17. Figure #19 shows an example of the use of voice commands to input city, state and zip code. The key idea is to minimize (or not use) free dictation that requires natural language processing by having a list of common choices, for instance, names of regional cities as voice commands that can be recognized and positive sound feedback can be provided. We hope this approach will allow us to achieve a higher recognition rate in spite of the noisy environment often found in the EMS field.

Table 1: Structured data fields captured using voice

1. Buttons press	7. Vital Signs
2. Fields Selection	8. Medications administered
3. Basic demographic data	9. Procedures
4. Chief Complaint	10. Servicing Hospital
5. Medical conditions	11. Narrative (free text using dictation)
6. Symptoms	12. Address (free text using dictation)

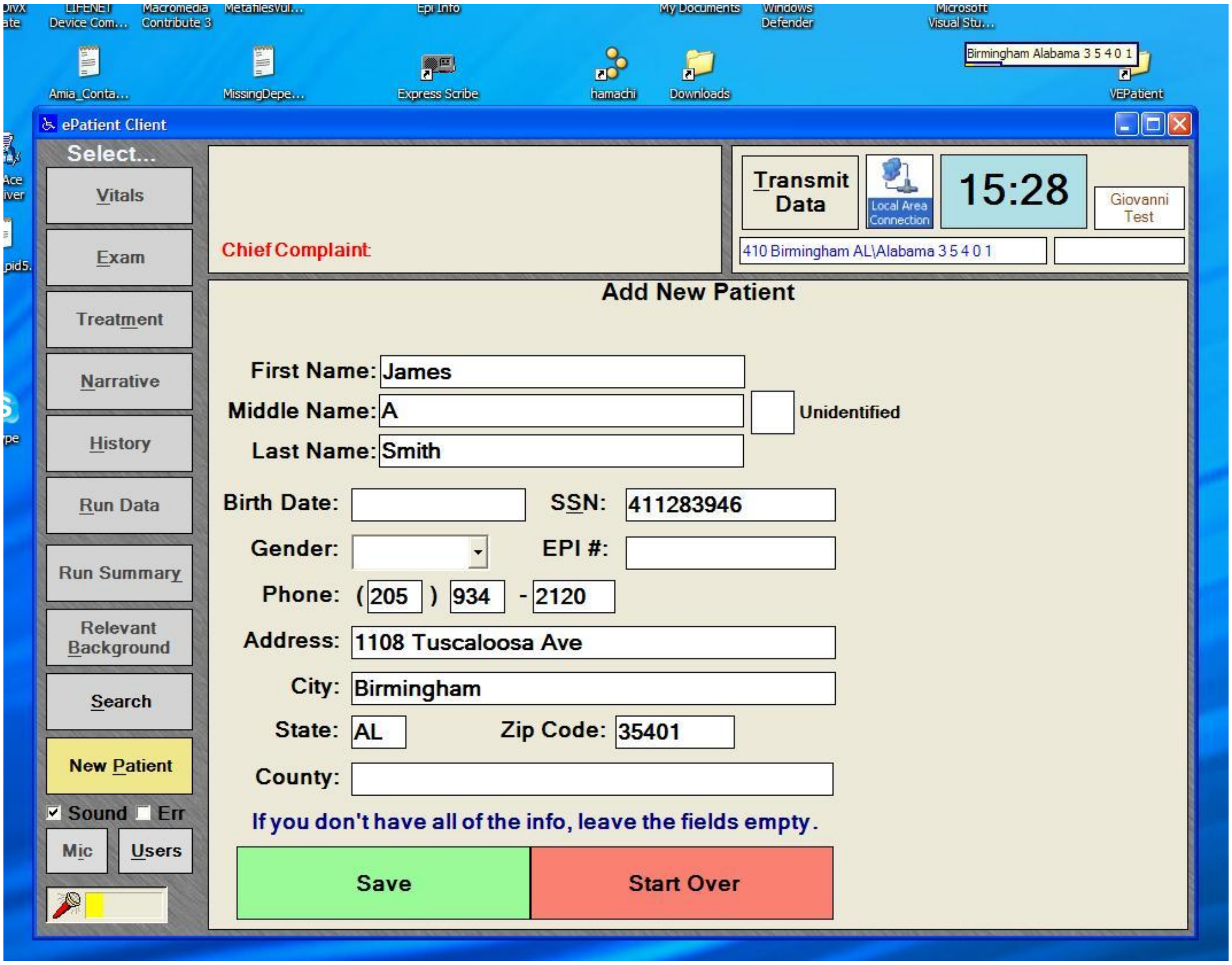
Table 2: Example Stroke Test Case	
Demography and Insurance Information: Name: James A Smith Age: 76 DOB: 10/04/1928 Gender: M SSN: 411-28-3946 Address: 1108 Tuscaloosa Ave Phone: 205-934-2120 **Chief Complaint:** Stroke **Other Symptoms (History/Exam Conditions):** Hypertension + Surgery 3 weeks – Bleeding disorder – Brain tumor – Anticoagulant – Peptic ulcer disease - **Past History (History/Medical Conditions):** Hypertension **Procedures:** 19:27 Airway-Intubation Two attempts 19:28 Airway-Bagged 19:32 Venous Access – Extremity One attempt	**Vital Signs:** 19:26: BP 246/138 Pulse 68 RR 8 Glucose 102 Skin Color: Normal Skin Condition: Moist Mental Status: Unresponsive Left Pupil: Reactive Right Pupil: Reactive 19:31: BP 238/136 Pulse 72 19:36: BP 224/124 Pulse 72 **Medications Administered:** 19:33 Normal Saline IV TKO Unchanged 19:34 Labetalol IV 10 mg **Servicing Hospital:** University of Alabama Hospital **Narrative:** Patient was having dinner, when he suddenly slumped forward unconscious. The wife called 911.

Figure #18. Dataflow of the vePCR:



The design of the vePCR utilized command & control speech recognition techniques only for structured data. The validation of the vePCR was incomplete since we only used six test cases and two well trained users. Also, the usability of the system has not been studied as the main objective was establishing a viable prototype. We plan to have EMS personnel use the prototype in the field to provide feedback on usability, additional features, the voice command set, and the scope of the vocabulary.

<u>Figure #19 - Capturing patient's City, State, and Zip Code:</u>



The voice command: "Birmingham Alabama 3 5 4 0 1" is recognized as: "410 Birmingham AL\Alabama 35401" (410 is the command number)

The application of speech recognition to enter structured data using "command & control" is definitely less error prone than using "dictation" for completing the vePCR. However, we need to address synchronization problems between the speech engine and the GUI caused by breathing sounds. To prove that speech recognition using command & control improves the EMS workflow requires additional studies.

Project #3 "Video Conferencing in the Pre-Hospital Environment"

Gary G. Grimes, Ph.D., Co-PI

A number of new initiatives for video research in emergency medicine and disaster management applications were identified in the fourth quarter of 2006 in planning the work for 2007 projects. The following initiatives either represent research presently in progress or under consideration for 2007: Continue work on low-cost high definition (HD) video for real time teleconferencing to support remote triage and treatment for emergency medicine and disaster medicine. Last year we conducted a number of successful experiments using low cost consumer HDV cameras for real time teleconferencing. This work leveraged off prior success experiments in real time teleconferencing using the standard definition (720 x 480) DV standard. The HDV standard appeared appealing because low cost cameras in the $3000 range are available with very high quality sensors and lenses and this price point was considerably less than the cost of comparable quality HD teleconferencing systems, which are priced in the half million dollar range. This work leveraged off prior experiments in DV in which we used the QVidia (now QVidium) software for much higher than typical standard definition two way real time teleconferencing. In these experiments we used our standard operational campus IP network to do IP LAN based conferences between the Business Engineering Complex and the Learning Resources Center on the UAB campus. Based on successful experiences we extended these experiments by using Internet 2 facilities between UAB and Columbia University in NYC. These experiments were also successful and we found that for most volume levels we didn't even need echo cancelling software in the audio channels. During 2006 we conducted successful HDV teleconferencing experiments on our campus using the QVidia software. However, we concluded that the in-camera digital encoding delay of about 0.6 seconds was too long to permit high quality real-time teleconferencing. Unlike the DV standard which uses the discrete cosine transform for intraframe compression, the HDV standard adds the motion estimation interframe compression found in MPEG-2. However, the excellent quality of the image and sound showed that this technology would be highly attractive, particularly at the price point, for one-way monitoring of a patient, a disaster scene, an accident scene, or a number of other applications in emergency medicine and disaster management. The most recently opportunity to surface here appeared in late 2006 when both Sony and Panasonic introduced high definition digital video cameras with built-in MPEG-4 encoders. These cameras were in the prosumer category, selling for as little as $1,000. Some have built in hard drives and some have built in Blu-Ray high definition DVD-writers to store and record the video. Because the bit rates are reduced so much, hard drives and writable high definition DVD's are practical as storage elements. These cameras are particularly attractive because they do not require I2 (Internet2) facilities for real-time video transmission or conferencing. However, although not specified, the encoding delay for the in-camera MPEG-4 encoding is probably too long. This is extrapolated from external hardware assisted MPEG-4 encoding boxes in which the encoding delay is fixed, but nevertheless between one and two seconds. This is obviously too slow to support real time bidirectional teleconferencing, but it is an attractive price point for transmission of real time high definition video over the standard Internet using ordinary DSL, CableModem, and satellite access. Only 1 to 3 Mb/s is required for MPEG-4 transmission.

The first hop for video links in an operational environment for emergency medicine and disaster management would conveniently be a wireless link in many cases. Examples of this are from a paramedic to an ambulance at an accident or disaster scene and from a fixed camera to a nearby shared transmission antenna. We are evaluating the digital signal performance requirements for a number of video streams including DV, HDV, MPEG-2, MPEG-4, and webcams and comparing then the capabilities of wireless links such as WiFi, WiMAX, Bluetooth, Zigbee, etc. We are also evaluating the possibilities of using these same links for wireless transmission of still images. Possibilities for experimentation are WiFi SD cards and the WiFi equipment available to link Canon digital single lens reflex (DSLR) camera to nearby desktop and laptop PC's. A graduate student is currently making the preliminary mapping study and experiments will follow soon. One of the major challenges to getting a more or less real time multimedia medical record put together for a patient is to have an extremely user friendly set of software tools that can easily combine textual data, graphical data, video clips, still images, and sound clips. Graduate student, Omkar Patkar, is currently making a thorough comparison of the software tool kits available for multimedia integration and is experimenting with it from the standpoint of minimally trained practitioners. He will also make some trial multimedia records using the best of these tools and compare them in terms of usability and the quality of the finished multimedia record. We have several presently un-staffed projects in the Project 3 video area. Two master's level students are coming onboard in Electrical and Computer Engineering in the next month so we expect that some of these tasks will be staffed soon.

1. Study combining video and still imaging for triage and treatment
2. Work on a way to get images to give an overall view of a disaster scene – maybe using multiple images automatically stitched together
3. Work on the video/imaging aspects of the portable blow up bed for emergency management
4. Work on concepts for a national or regional disaster command/control center using I2
5. Work on a campus server system for canned and real-time HD video.
6. Study high definition video communication for remote triage and treatment at a small emergency room in Alabama over I2.
7. Study how to coordinate in vehicle real time traffic videos with emergency vehicle location, velocity, and previous transport patterns.

Dr. Gary Grimes has presented the group with several types of video services that we need to address for this project:

1. Multipoint video/audio teleconferencing
    a. Identify scenarios where video or videoconferencing adds value in emergency care:
        i. Multi-way calls and/or video for death-in-the-field
        ii. Multi-way calls to document patient refusals
        iii. Addition of physiological waveform data such as oxygen level and CO2 level via video-conferencing data channels
2. Point-to-point video/audio teleconferencing
3. Two way high quality real-time video/audio
4. One way high quality real time video/audio
5. Store and forward high quality video/audio
6. Video on demand from server for medical education etc.
7. Real time video sent wirelessly to handheld device

    a. Provide up-to-date videoconferencing equipment to project team for use by the team for collaboration/communication
8. Obtain multi-point connection support for the project
    a. Begin evaluation of currently available wireless video/voip devices
    b. Begin evaluation of wireless technologies that can be used by mobile vehicles.
    c. Begin design of laboratory setup to explore utility of various video resolutions in the lab; progressively move away from idealized lab environment to noisy wireless environment; identify usability parameters
9. Real time video sent wirelessly to handheld device

There are several types of networks to deliver these services which are as follows:

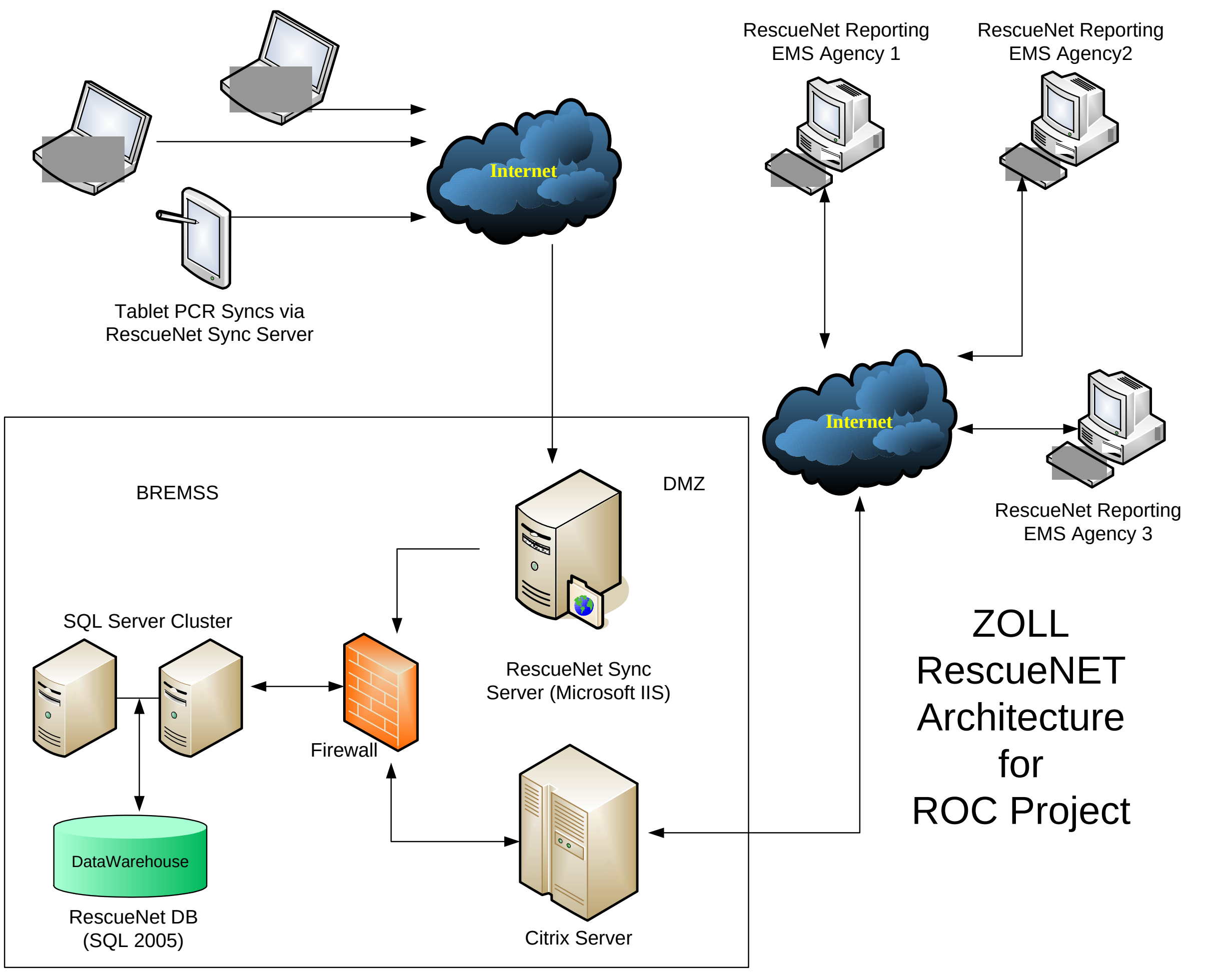
1. Standard Ethernet networking – Fast Ethernet/Gigabit Ethernet
2. Video over IP
3. Fiber optic overlay network (multimode or single mode, switched or unswitched)
4. Low data rate video over cellular and 802.11a, b, g, n

With Dr. Grimes we have continued pursuing our ideas regarding low-cost broadcast quality video conferencing. We believe a test bed that provides the upper limit (i.e., the best quality and best performance) will not only be an “eye-opener” to the medical community but also a “reference point” against which other video technologies can be compared. While this technology will not be suitable for EMS field operation in the near future, it is realistic in the optically wired campus networks.

Project #4 "Supporting EMS in Health and Disaster Management"

Collaboration with Resuscitation Outcomes Consortium (ROC)

To expand our test bed area to "Real World" EMS agencies, we continue to work with the Alabama Resuscitation Center (ARC) which is a member of the Resuscitation Outcomes Consortium (ROC), a newly formed clinical network focusing on research in the area of pre-hospital cardiopulmonary arrest and severe traumatic injury. We anticipate that by coordinating our efforts with the ARC group we can begin to gather real "live" data from the field for evaluation of our system in the pre-hospital environment. The biggest change to this partnership in the first quarter is the decision to not use Medtronic's "Life Net EMS" for the patient care report but to instead go with Zoll's "Rescue Net" due to Medtronic's inability to provide the necessary software support for their system.



We assisted the UAB ROC team with technical assistance and hardware for the SQL Server Cluster and the Citrix Servers (3 rack mountable Dell Servers). Software licenses are provided by ROC (or participating companies). All equipment is housed at BREMSS' TCC (Trauma Communication Center), authorized to maintain clinical data.

We hope our partnership with ROC will enable us to perform usability studies of EMS personnel gathering data clinical data at several ambulance agencies within the surrounding areas of Birmingham (BREMSS region). EMS personnel of those agencies will be provided training by ROC on Zoll's Rescue Net data management software and Medtronic's automatic external defibrillators (AED). This pool of EMS personnel that have been trained and have first hand knowledge of the EMS environment will provide the expertise and feedback that we are not able to acquire on our own.

Background on Alabama ROC [3]:
Provided by Shannon Stephens, EMT-P, Project Director & Clinical Research Coordinator, Department of Emergency Medicine, UAB.

ROC consists of 10 Regional Clinical Centers (RCCs) and a Data and Coordinating Center (DCC) that will provide the necessary infrastructure to conduct multiple collaborative trials to aid rapid translation of promising scientific and clinical advances to improve resuscitation outcomes. The database began collecting data from the BREMSS TCC in December of 2005. This database will track patients throughout the care process until discharge from hospital; including follow-up exams not only with this provide data on current EMS care but also allow for better designed studies in the future. In its second year, the Alabama Resuscitation Center (ARC) furthered its commitment to the success of the ROC by assisting in the development and beginning the groundwork for locally implementing interventional clinical trials; recruiting and training newly involved clinicians and scientists interested in resuscitation; participating on numerous important ROC task forces and committees; and collaborating with national, regional, and local ROC partners, including members from the local citizen-community. The ARC also expanded the reach of available Internet-based information about resuscitation science at UAB by creating a Website (www.uab.edu/arc), launched in September of 2005. The Website offers information about former and ongoing trials or studies related to the mission of ROC, as well as specific information about ARC's leadership and involvement. This Website also offers a useful feedback forum for public disclosure, community consultation, and background statistics concerning the public health burden associated with cardiac arrest and trauma in Alabama. There are also Web-links to other sources of related information, including the main NHLBI-ROC Website, NIH-NHLBI Website, and other RCC and DCC Websites. Due in part to the assistance provided by BREMSS, local EMS agencies involved with ROC studies are submitting paper copies of Run Reports, thereby allowing for enhanced quality improvement and control of Epistry data. Trials may evaluate existing or new therapies (such as pharmacologic immune modulators) as well as clinical management strategies (such as new resuscitative fluids, novel hemorrhage control strategies, the use of cerebral protection and neurologic preservation, metabolically directed therapies and alternative methods of delivering CPR or defibrillation).

The ARC has established a local network of more than a dozen local EMS agencies committed to recruiting and enrolling patients into ROC trials. The ARC-investigators meet regularly with these EMS leaders, whose membership includes EMS service chiefs, training officers, and administrators from the greater Birmingham area to review ROC protocols. These meetings also have been used to discuss logistical issues related to protocol implementation, data collection, and training needs. As a result of these positive interactions, the ARC has added three new EMS agencies to the local ROC network. These newly added agencies will further expand the ability of the ARC to successfully implement interventional trials. The ARC has also developed effective working relationships with the UAB-Emergency Department (ED) staff and nurse managers representing 11 local hospitals involved with the ROC net-work. In February, UAB-ED staff received two in-service trainings about ROC protocols. During these training sessions, UAB-ED staff received training on entry criteria for both cardiac- and trauma-protocols, as well as necessary patient-tracking methods for both the ARC and the Trauma Registry. In March 2006, ARC-staff met with the nurse managers mentioned above to present protocol overviews, reduce concerns about excess work imposed by ROC-participation, and clarify the method for transferring data.

- Cardiovascular disease (CVD) is the leading cause of death in Alabama.
- 63% of Alabama’s CVD deaths are from sudden cardiac death
- Alabama has the second highest rate of out of hospital cardiac arrest (OOH-CA) in the country.
- Alabama’s OOH-CA survival rate to hospital discharge is estimated to be less than 1%. The national average is estimated to be between 4-5% percent.
- Alabama mirrors US statistics identifying trauma as the leading cause of death for those between the ages of 1 and 34.
- Injuries alone account for approximately 3,200 deaths each year in Alabama.
- Alabama has one of the highest rates of unintentional motor vehicle traffic-related deaths in the country (26.43 deaths/100,000 population) compared to the national average (16.4 deaths/100,000).

The local network of partners listed below will assist ARC in facilitating access to patients and conducting the proposed clinical studies.

- Alabama Hospital Association
- Birmingham Regional Emergency Medical Services System
- The Children’s Hospital of Alabama
- University Hospital, UAB
- UAB Center for Emergency Care and Disaster Preparedness
- UAB Center for Injury Sciences
- UAB Center for Surgical Research
- UAB Department of Cardiology
- UAB Department of Emergency Medicine
- UAB Department of Pediatrics
- UAB Department of Surgery (Trauma)

The Birmingham regional Emergency Medical Services (EMS) agencies collaborating with the ARC include:

- Alabama Lifesaver
- Birmingham Fire and Rescue Service
- Bessemer Fire Department
- Centerpoint Fire Department
- Homewood Fire Department

- Hoover Fire and Rescue Service
- Pelham Fire Department
- Regional Paramedic Services in Walker County
- Trussville Fire Department
- Vestavia Hills Fire Department
- Birmingham Regional Emergency Medical Services System

Project Abstract, Posters, Papers, Tutorials:

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2. **Mobile Multimedia in Pre-Hospital Emergency Care**, Manish Mittal, Jill Gemmill, Helmuth Orthner, Ninad Mishra, 2nd International Conference on Advances in Mobile Multimedia, Bali – Indonesia, Sept 22-24, 2004 (accepted but withdrawn for lack of funding for international travel).
3. **Personalized online information search and visualization**, Dongquan Chen, Helmuth F. Orthner, and Susan M Sell; BMC Medical Informatics and Decision Making 2005, 5:6; March 14, 2005 (www.biomedcentral.com/1472-6947/5/6).
4. **Information Infrastructure for Emergency Medical Services**, Helmuth F Orthner, Ninad Mishra, Thomas Terndrup, Joseph Acker, Gary Grimes, Jill Gemmill, Marcie Battles; Proceedings of the AMIA 2005 Annual Symposium, October 22-26; Poster; p. 1067.
5. **A Study Design for Comparing Electronic Patient Care Report (ePCR) with Paper PCR in Pre-Hospital Care**, Devashish Saini, Amarinder Sandhu, Mandar M Gori, and Helmuth F. Orthner; Proceedings of the AMIA 2005 Annual Symposium, October 22-26 (Poster nominated for an Award); p. 1103.
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8. **Online Medical Control in Protocols and Practice**, Devashish Saini, Mandar M Gori, Muzna Mirza, Shannon W. Stephens, and Helmuth F Orthner; Proceedings of the Southeastern SAEM Regional Conference, Greensboro, NC, March 24-25, 2006 (abstract accepted #1083).
9. **Requirements Analysis for Pre-Hospital Electronic Documentation**, Gori M. Mandar, Devashish Saini, Muzna Mirza, Marcie H Battles, David G Nathan, and Helmuth F Orthner, Proceedings of the Southeastern SAEM Regional Conference, Greensboro, NC, March 24-25, 2006 (abstract accepted #1114).

10. **Comparison of Efficiency of Emergency Medical Dispatching Algorithms**; Mandar M Gori, Devashish Saini, Marcie H Battles, and Helmuth F Orthner, Proceedings of the AMIA 2005 Spring Congress, Phoenix, AZ, May 16-18, 2006 (poster #18)
11. **Chest Pain and Validity of an Emergency Medical Dispatch Algorithm**; Ninad Mishra, Helmuth F Orthner, and David C. Pigott; Proceedings of the AMIA 2006 Symposium, Washington, DC, Nov 11-15, 2006 (Abstract p. 1035).
12. **Application of Speech Recognition Data Entry Enhancements in an Electronic Patient Care Report (ePCR)**, Giovanni Mazza, Marcie H Battles, and Helmuth F Orthner; Proceedings of the AMIA 2006 Symposium, Washington, DC, Nov 11-15, 2006 (Abstract p. 1026).
13. **Development and Testing of an Algorithm for Efficient Resource Positioning in Pre-Hospital Emergency Care**, Devashish Saini, Giovanni Mazza, Najaf Shah, Muzna Mirza, Mandar M. Gori, Hari K Nandigam, and Helmuth F Orthner; Proceedings of the AMIA 2006 Symposium, Washington, DC, Nov 11-15, 2006 (Abstract p. 1083).
14. **A Regional Database of Antidote Availability**, Muzna Mirza, Devashish Saini, Mary A Dickens, Ziad Kazzi, and Helmuth F Orthner; Proceedings of the AMIA 2006 Symposium, Washington, DC, Nov 11-15, 2006 (Abstract p. 1034).
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16. **Expert Validation of the Knowledge Base for E-CAD - a Pre-hospital Dispatch Triage Decision Support System**, Muzna Mirza, Devashish Saini, Todd B. Brown, Helmuth F. Orthner, Giovanni Mazza, and Marcie M. Battles; submitted to AMIA's Annual Fall 2007 Symposium (accepted)
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18. **Wireless Communication and Mobile Computing in Healthcare**, Helmuth F. Orthner, PhD, Tutorial at the AMIA Fall 2007 Symposium (accepted)
19. **Generation of Context-specific Electronic Patient Care Reports (ePCR) using Domain-Specific Modeling**, Rohit Shenvi, Giovanni Mazza, Devashish Saini, Helmuth Orthner, Jeff Gray, Workshop on Model-based Trustworthy Health Information Systems (MOTHIS) in conjunction with the 10th ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (Models 2007); Sept 30 to Oct 5, 2007; (accepted)

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