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Advanced Health and Disaster Aid Network[1]

ABSTRACT

Responding to Mass Casualty Incidents (MCI) poses a significant challenge to the emergency response community because of the large number of victims relative to available care providers and resources. Emergency Medical Service (EMS) officers must coordinate transportation of victims to care facilities often with insufficient information on available beds or the clinical resources required for the situation at hand. Furthermore, Public Health organizations must assess the effect of the incident on community health and the evolving needs of the ongoing response, often with limited ability to monitor the situation. In these chaotic environments, patients are often neglected for extended periods of time, some are not treated effectively, and some with minor injuries might depart the scene without the awareness of the response team. As a group the different organizations involved in a large-scale casualty incident are not sufficiently informed about the event to effectively manage the situation. As a result the response effort is often subject to time delays, inaccuracies and worsening conditions.

Present day triage and patient monitoring requires emergency responders to manually obtain, sort, and share information on each victim at a disaster scene with paper-based methods and radio communications. The Advanced Health and Disaster Aid Network (AID-N) system has the capability of triaging and monitoring disaster victims and making this information available in real time to each part of the emergency response team in an integrated and intuitive fashion.

The AID-N System provides the capability for multiple first responder disciplines (EMS, Fire, and Police) and multiple health service facilities (hospitals, auxiliary care centers, public health departments) from different jurisdictions using different information systems to coordinate their response efforts by sharing real-time information. The AID-N testbed system uses a service-oriented architecture (SOA) that has shared data models of disaster scenarios to support the exchange of data between heterogeneous systems. The system provides integration and interoperation with four data collection subsystems developed by APL and the AID-N project: 1) a mesh network of wearable sensors for patients involved in a disaster (CodeBlue) developed in conjunction with Harvard University, 2) a web-based disaster information portal called the Emergency Response Information Center (ERIC), 3) a PDA used by first responders at disaster scenes to input data, called the Surveillance and Incident Reporting PDA (SIRP), and 4) a hand-launched autonomous unattended aerial vehicle (AUV), the latter developed under an APL IR&D project .

In addition to the data collection at the scene, we have also developed interfaces with three deployed systems: 1) the ESSENCE syndromic surveillance system used in the National Capital

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Scaleable Information Infrastructure Program

Region, 2) a pre-hospital patient care reporting software system used on ambulances in Arlington County, Virginia (MICHAELS), and 3) a hazardous material reference software system (WISER) developed by the National Library Medicine

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The AID-N system was demonstrated in a simulated mass casualty exercise at Montgomery Blair High School with Montgomery County Fire and Rescue on August 5, 2006.

1. INTRODUCTION

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) developed the Advanced Health and Disaster Aid Network (AID-N) for the Scaleable Information Infrastructure Program under contract N01-LM-3-3516 with the National Library of Medicine (NLM) for the period of performance from October 2003 to September 2007. AID-N is a testbed for technologies that enable emergency medical service personnel to more efficiently triage, track, and transport patients while sharing real-time patient information and conditions at a disaster scene with the entire emergency response community. By integrating technologies such as electronic triage tags, wearable vital sign sensors, ad-hoc wireless networks, web portals, and teleconferencing, AID-N dramatically enhances collaboration between personnel at all levels of the emergency response community. The AID-N approach has great potential for improving today's emergency response system, especially in mass casualty situations. The AID-N team is led by JHU/APL and includes the Montgomery County Department of Health and Human Services, Montgomery County Fire and Rescue Service, Suburban Hospital Emergency Department, Johns Hopkins Medical Institutions Department of Medical Informatics, ECRI Institute, OPTIMUS Corporation, and Montgomery Blair High School. Project partnerships and collaborations were also established with Harvard University's CodeBlue project, University of Virginia, National Library of Medicine's WISER project, and University of Maryland project on wearable sensors for first responders.

The objectives of the project are to:

- Collect, track and report patient and incident information for large scale emergency situations
- Focus on the <u>medical</u> aspects of an emergency response
- Improve:
    - Collaboration among involved organizations
    - Keeping track of the location and condition of both patients (victims) and providers
    - Real-time situational awareness
- Build a technology testbed taking advantage of existing technology, products, and prototypes as much as possible.
- Develop a system architecture and network system that is scaleable to:
    - All responder and emergency groups
    - Multiple regions

1.1 Project Organization

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) was the lead organization for the AID-N project. Dr. David White was the Principal Investigator and Program Manager and Tia Gao the Project Manager. The initial team organization included five subcontractors and one partner. Three of these subcontractors were from the local emergency medicine user community, namely, Suburban Hospital Emergency Department (Cindy Notobartolo and Patricia Hawes), Montgomery County Department of Health and Human Services (Kathy Hurt-Mullen), and the Johns Hopkins Medical Institutions (Dr. Harold Lehmann). The other two subcontractors were the ECRI Institute (Jonathan Gaev), an independent medical device testing company, and OPTIMUS Corporation (Cliff Andrews), developer of an existing ambulance triage system called Michaels. Montgomery Blair High School (Dr. Glenda Torrence) was a partner providing an ideal location for conducting field tests site. MBHS was also an important resource for summer interns owing to their magnet program in science, mathematics, and computer science. All of these organizations are located in the State of Maryland except the ECRI Institute, located in Plymouth Meeting, Pennsylvania.

During the project we formed a number of collaborative efforts with additional interested user groups and developers, who became critical members of the team. These include collaborations with Harvard University (Matt Welsh, PhD) on the CodeBlue wireless mesh network and mote development; University of Virginia (Leo Selavo, PhD) on circuit board design and development; Montgomery County Department of Homeland Security (Gordon Aoyagi, Director) for approving EMS support and providing scenario guidance; Montgomery County Fire and Rescue (Chief Daniel Blankfeld) providing and organizing all EMS personnel participating in the field test; University of Maryland (Gilmer Blankenship, PhD and David Tahmoush, PhD) on software development; and Marco de Palma, Next Century Corporation and Marti Szczur, National Library of Medicine on the WISER hazmat PDA. We also consulted with a number of valued advisors including Knox Andress, R.N., Christus Schumpert Health System on emergency medicine and concept formulation; Charles ‘Chuck’ Paidas, M.D., University of Southern Florida, Tampa, Director Pediatric Surgery on trauma care and emergency response scenarios; David Aylward and Judith Woodhall, ComCare Alliance on emergency response requirements and data standards; Ron Stickley, Arlington Emergency Medical Services on EMS practices and procedures; and Jerry Overton, Executive Director, Richmond Ambulance Authority on EMS practices and technology insertion.

The project was organized as a three phase effort comprising requirements analysis, technology development, and test and evaluation. The requirements analysis processes and evaluation used a hands-on process with the user community that involved incrementally building prototypes (devices, graphical user interfaces, etc.), demonstrating them to the users and evaluators at each step in the development, and getting their feedback. This cyclical build-demonstrate-rebuild process became a very effective development process. By showing the users prototypes, starting with design concepts and continuing at each stage of the development, they were better able to understand its utility and how it would fit into their business practices. As a result they were able to provide valuable feedback on how the prototype/system should be changed to fit their needs. A key lesson learned is to involve the user community in the development and evaluation process from start to finish.

2. SYSTEM DESCRIPTION

Emergency Medical Services, hospital emergency departments, Public Health, remote emergency care specialists, biosurveillance systems, computer-aided dispatch, local emergency operations centers, transportation centers, city emergency managers, and public works are representative of the organizations that may be required to participate in a specific mass casualty incident. This project concentrated on those organizations most likely to participate in a disaster situation, namely, EMS, hospital emergency departments, and Public Health. In addition, we included interfaces to the ESSENCE biosurveillance system, and the Michaels ambulance triage system. However, the system architecture and communication network was designed to be scaleable to all involved organizations plus operation over extended geographic areas.

Figure 1 provides an overview of the AID-N testbed or system. Electronic triage tags with built in pulse oximeter and gps are placed on the wrist of patients at a scene. The patients triage level set by the paramedic, the heart rate and specific oxygen, and the location are relayed to laptops at the scene via a Zigbee (802.15.4) link. The laptops are manned by the Incident Commander and other EMS officers located at the scene. These laptops in turn send the information to a central server via the Internet using either EVDO broadband cellular links or local area network WiFi (802.11), if available. The handheld PDAs (called Surveillance Incident Reporting PDA or SIRP) are used by medics and assistants to collect patient chief complaint, treatment provided at the scene, and identification information with the aid of a built-in driver-license barcode scanner and camera. Collectively this information establishes a pre-hospital patient record, which continuously transferred to the central server via WiFi or EVDO links.

This patient and disaster situation data can then be queried and viewed by the response community via a web portal. Customized views or portlets are provided for the different users in the community, namely, hospital emergency departments, Public Health, and emergency management personnel at an Emergency Operations Center. In addition, a capability was developed to send the ambulance run sheet data to the ESSENCE server using web services.

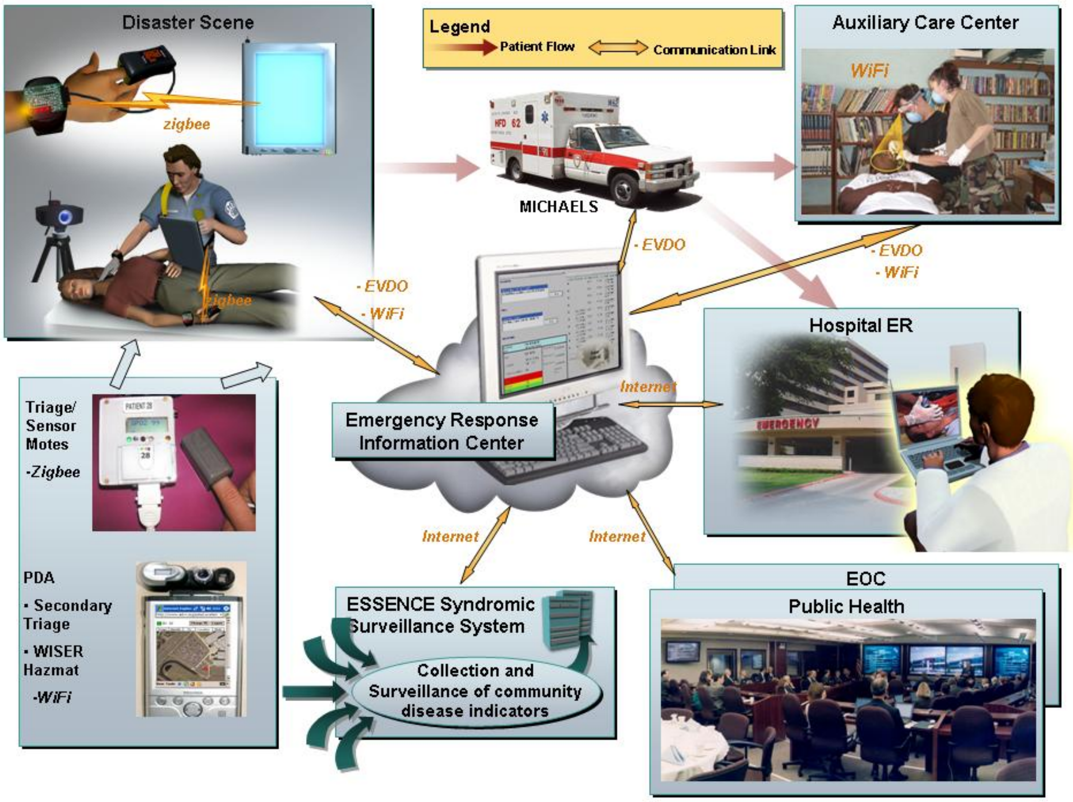

Figure 1 AID-N System Diagram

3. WEB PORTAL: EMERGENCY RESPONSE INFORMATION CENTER

The ERIC server is a centralized web-based information portal for situational awareness and unified control of the emergency medical response activities of hospital emergency departments, auxiliary care centers, first responders, public health, and disease surveillance activities, and the communications system during a disaster situation. It is designed to use distributed web based applications and provide users a pathway to the information via portlets. Each portlet wraps a given web based resource. They range from links to individuals and resources, Really Simple Syndication (RSS feeds), Web pages, web clips , web service wrappers on existing functionality and access to new and existing databases. ERIC employs a service-oriented architecture (SOA) with wrappers on each network node to collect information in a scalable, secure, and flexible manner. It then uses servlets and portlets to employ a map-centered web interface for quick and intuitive access to the information collected. The system was designed with Visual Studio 2005 in ASP.NET 2.0.

The ERIC server, shown in Figure 2, is connected via web services to the three systems located at the disaster scene on the left side of the Figure. This includes interfacing with the one or more EMS officer laptops (labeled as CodeBlue Patient Tracking in the Figure), which are collecting patient data via Motes mesh network, the WISER hazmat PDA, and the SIRP/PDA's, which are used to collect patient identification information and secondary treatment/triage data. The Motes and SIRP were developed by the AID-N project, while the Wireless Information System for Emergency Responders (WISER), a hazardous material reference software system, is an example of developing a web service to interface with an existing system. WISER was developed by Next Century Corporation and the National Library of Medicine. It helps first responders identify hazardous materials at a disaster scenario and provides instructions for how to treat and contain those materials. AID-N receives this data through a web service and the hazard information is then distributed to the incoming responders and disaster managers in a context-specific way.

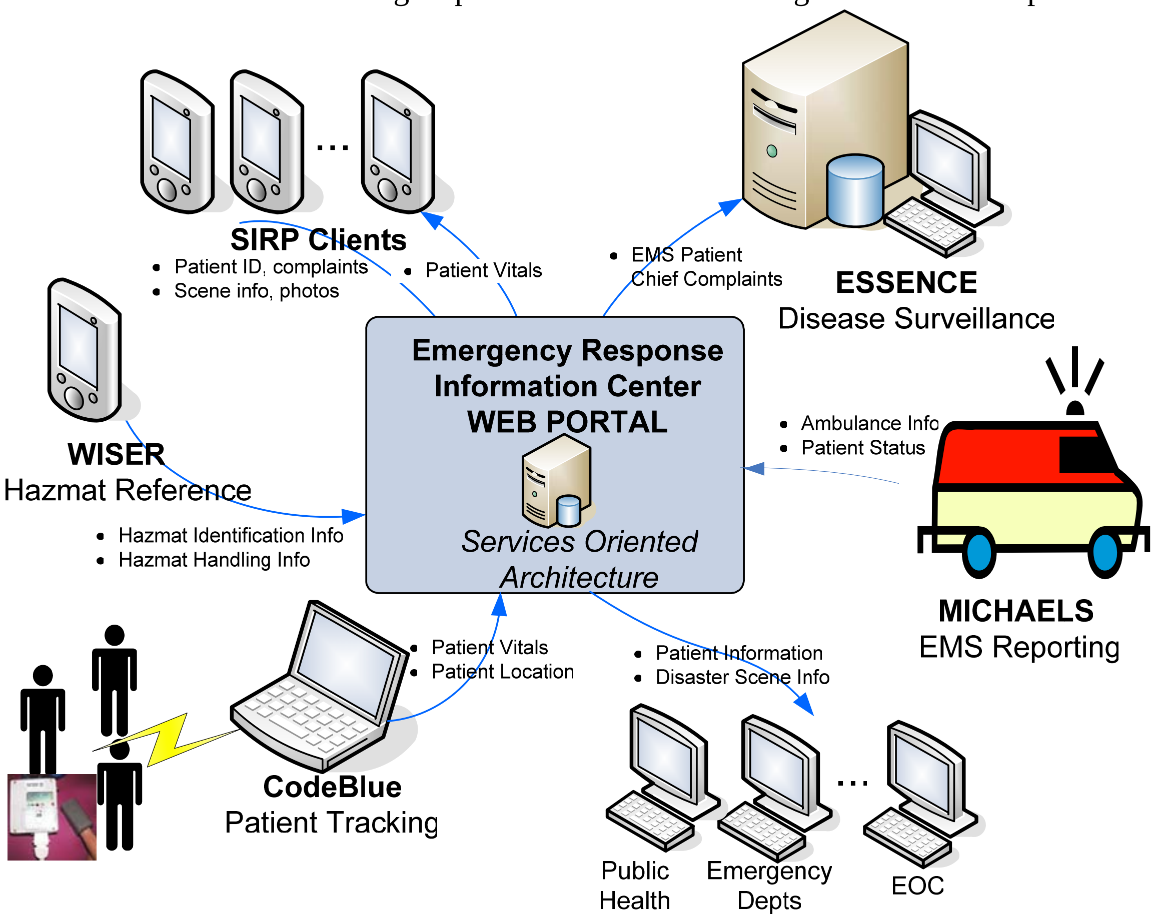

Figure 2. ERIC Web Portal

In addition to information collected at the scene, web services were implemented to interface with two other existing emergency response systems: a pre-hospital patient care reporting software system (MICHAELS), and a syndromic surveillance system (ESSENCE). The MICHAELS system is a pre-hospital emergency incident reporting application that is operating in Arlington County's ambulance fleet. (See Figure 3) MICHAELS software transmits patient, disaster, and ambulance information to AID-N through web services where the data are made available to other applications. The Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE) is the disease surveillance system in the National Capital Region. It collects health indicator data from multiple sources to assist epidemiologists to detect and analyze anomalous disease events. Using an AID-N web service, ESSENCE consumes the data produced by MICHAELS ambulance system.

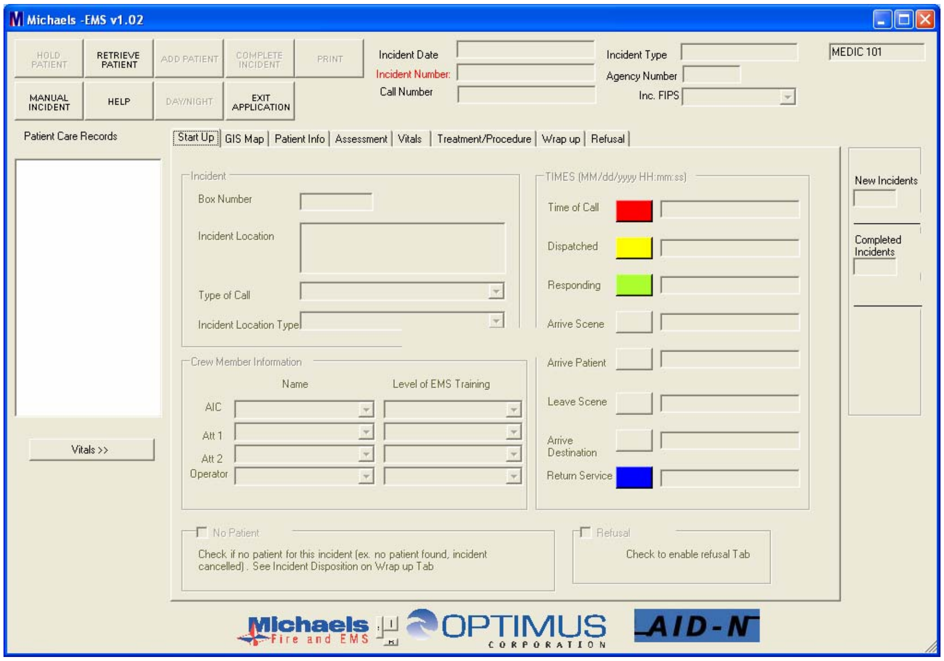

Figure 3. Michaels Prehospital Patient Reporting System

In summary the services provided by the ERIC web portal are:

<u>Disaster scene</u>

- Wireless vital sign monitoring and indoor and outdoor location tracking for patients and care providers
- Video surveillance camera feeds from the incident scene
- Web portal for incident commanders providing status and situational awareness of the disaster scene

<u>Ambulance</u>

- Location tracking
- Updating patient records (Michaels)

<u>Auxiliary care Center</u>

- Access to remote mentors for triage and treatment support via tele-mentoring
- Wireless vital sign monitoring and indoor and outdoor location tracking for patients and care providers

<u>Hospital ED</u>

- Crucial information on relative degree of severity of situation
- Advance knowledge of numbers and types of injuries allowing for proper preparation before patients arrive

- Tele-mentoring support to Disaster scene and to Auxiliary care center

<u>Auxiliary Information</u>

- List of active incidents in the region
- Start time, current time and elapsed time for the local incident
- Weather conditions and alerts
- Traffic alerts.

Examples of the customized web portal views are described below.

Web Portlets for EMS Officers.

The incident commander has overall responsibility for the response effort and requires the broadest range of information to improve situational awareness. With this system they can enter command information and have the flexibility to customize their views of the situation as required. This could include, for example, the number and location of patients at the scene for each triage color, or the location of hot/cold zones and resources plotted on an overhead map of the disaster scene. An example of one screen is shown in Figure 4.

In addition to the Incident Commander other EMS or Fire and Rescue officers could be directed to the site depending on the scale and type of incident. In our Mass Casualty Incident Field Test, discussed below, we had two additional officers, a Treatment and Triage Officer and a Transport Officer. A sample screen for these officers is shown in Figures 5.

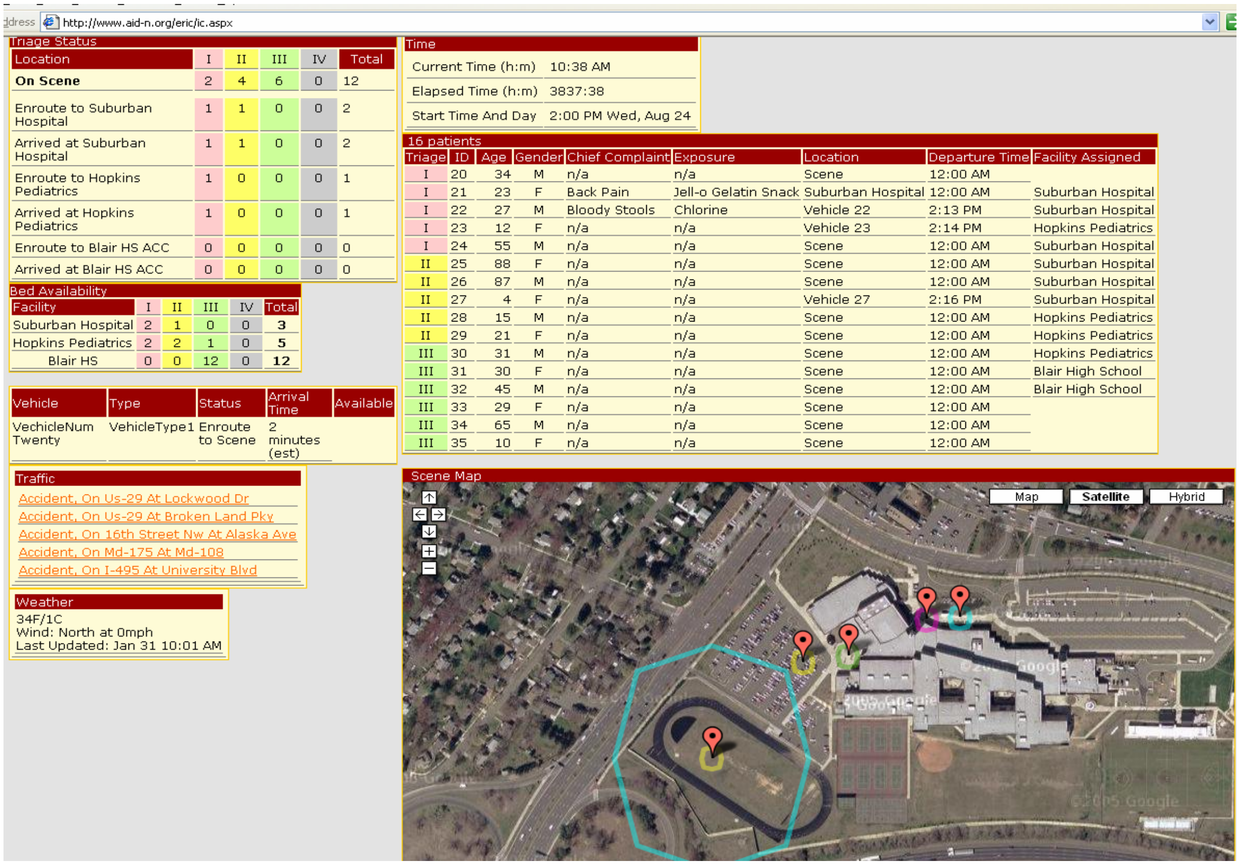

Figure 4. Example Web Portal View for the Incident Commander

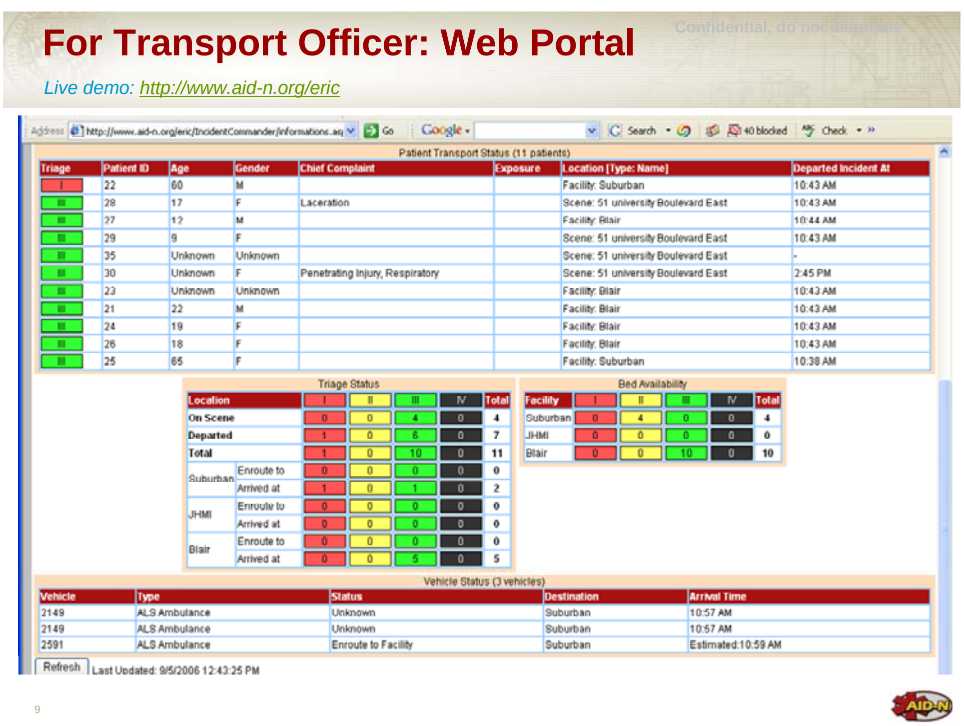

Figure 5. Web Portal View for the Transport Officer

Web Portal for Emergency Department.

3.1 Emergency department personnel can login to the portal to retrieve information about the patients who are being transported to their hospital.

Figure 6. 6 shows a sample screenshot.

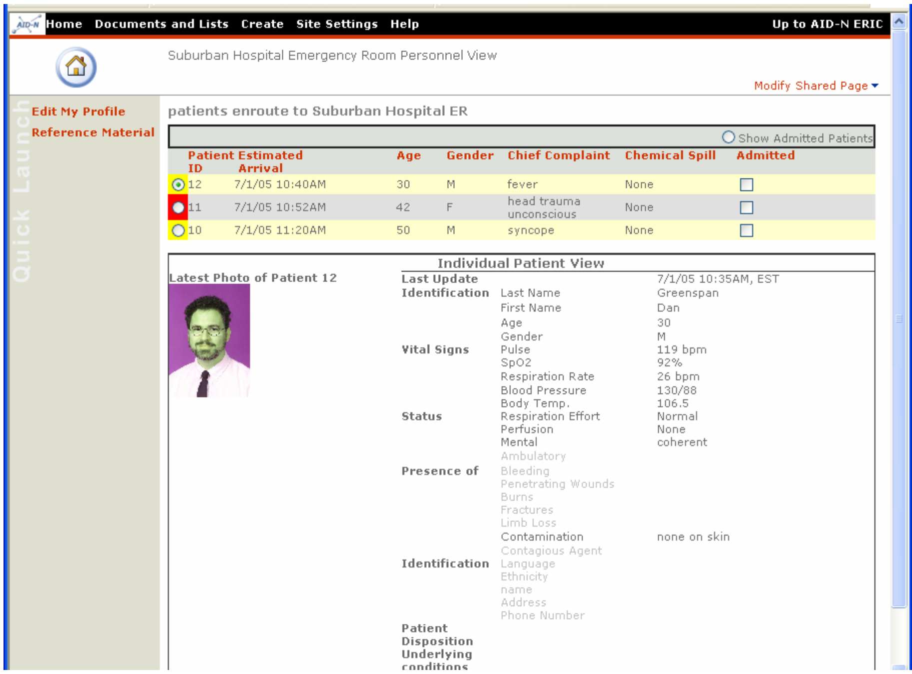

Figure 6. Web portal view for emergency departments

4. WEARABLE ELECTRONIC TRIAGE TAGS AND VITAL SIGN SENSORS

Our patient monitoring and tracking system extends upon the CodeBlue project from Harvard University. A wearable computer attached to the patient's wrist, commonly known as smart dust or a mote, forms an ad hoc wireless network that can be accessed by a portable PC. Several peripheral devices have been integrated with the mote, including a GPS receiver, a pulse oximeter, a blood pressure sensor, and an electronic triage tag. The current versions of these devices are shown in Figure 7.

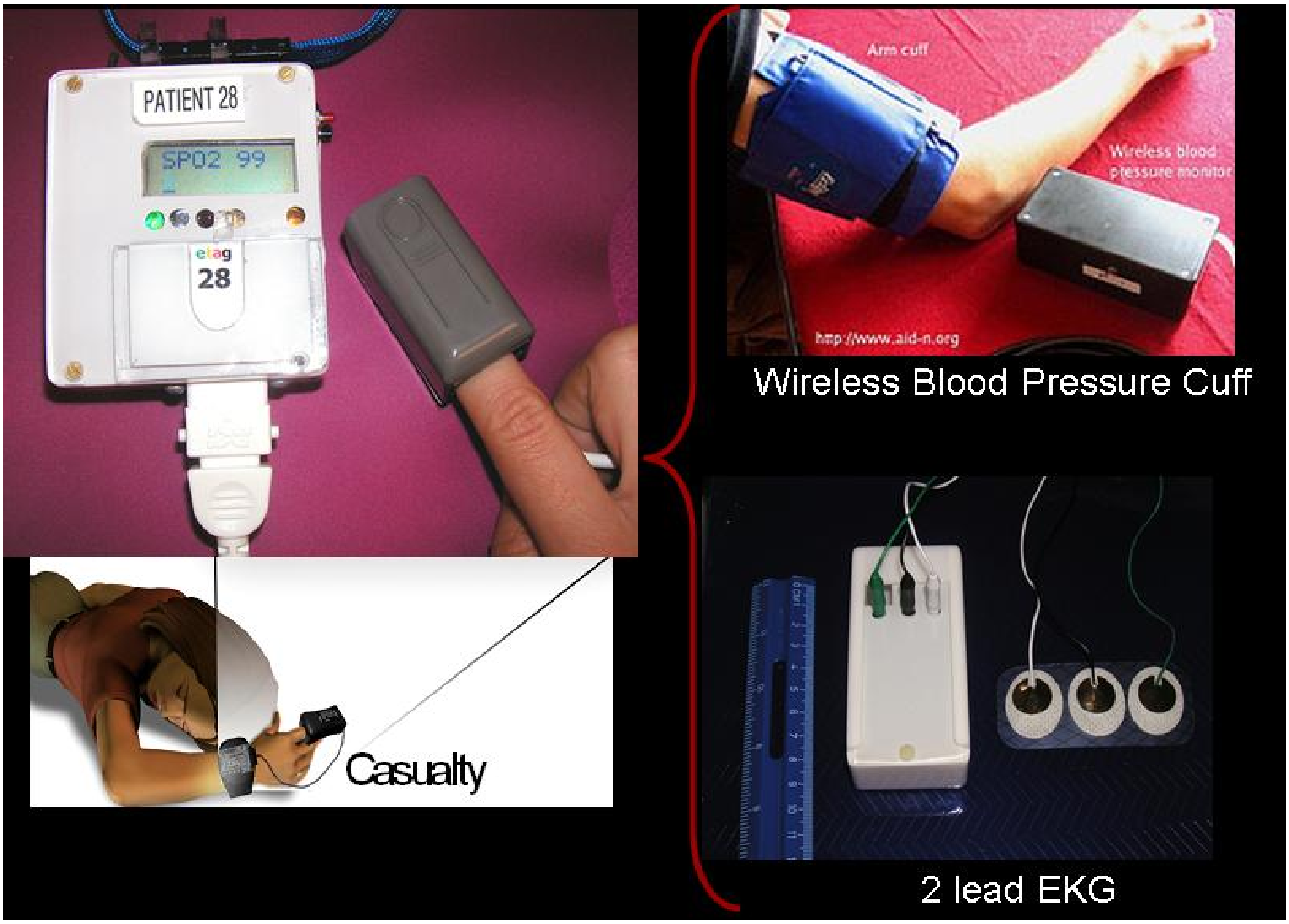

Figure 7. Mote Vital Sign Sensors: Pulse Oximiter, BP Cuff, and EKG

- **Pulse oximeter.** A Smiths Micro Power Oximeter Board (MPOB) is used to communicate between a finger-clip pulse-oximeter and the MICAz mote. The MPOB allows for measurements of blood oxygen saturation and pulse rate with a range of 30-254 bpm, accurate to within 2 bpm or 2%.
- **Electronic triage tag**. The electronic triage tag allows the medic to set the triage color (red/yellow/green) of the patient at the push of a button. It replaces the paper triage tags that are commonly used by medics today. We have made 10 printed circuit boards that can be neatly stacked onto the mote. The circuit diagram for this is shown in Figure .
- **Upper arm blood pressure sensor**. An OEM Advantage Mini device from SunTech Medical has been integrated into the hardware suite. This device consists of an upper arm cuff and oscillometry with step deflation to measure blood pressure. The blood pressure sensor board communicates through a TTL serial communication port, but since the MICAz mote does not support direct serial connections, a ribbon cable had to be custom made to allow communication. The device takes measurement ranges from 20-260 mmHg for adults and 20-160 mmHg for pediatrics. We chose this sensor for its suitability for field use as it

has been designed to be motion-tolerant, allowing for use in chaotic environments where patients may not be holding still during readings.

- **GPS receiver**. A GPS SiRF chip for outdoor geo-location positioning of both patients and providers. Coordinates can be plotted on an overhead imagery map to improve situational awareness of a disaster scene.
- **MoteTrac receiver**. Mote devices have on board capabilities to support an indoor location sensor. MoteTrac uses triangularization on the signal strengths from a grid of beacon motes (discussed further below). Measured radio signals are correlated against baseline measurements and then calculations can be made to pinpoint the location of a particular mote.

Software Capabilities

- **Ad-Hoc Mesh Networking Software**

Harvard University's Codeblue project serves as the foundation for the ad-hoc networking functionality. CodeBlue is a distributed wireless sensor network for sensing and transmitting vital signs and geo-location data.

- **Java Graphical User Interface (GUI)**.

From the Tablet PC on the scene, the medic has the ability to view information for patients in their area of care from a graphical user interface (GUI). The GUI, Figure 8, was developed using Java (J2SE 5.0 with Swing libraries) and has the following features:

Patient Management

- A Summary panel listing all patients, along with their triage color, pulse rate, blood oxygenation level, and blood pressure.
- The ability to sort patients based on their triage color with red patients at the top and green patients at the bottom.
- The ability to send a signal to a given patients mote for it to blink and or buzz to support localizing a particular patient quickly.
- Counts the elapsed time since the patient has been triaged.

Vital Signs Monitoring

- A summary panel listing all patient alerts, with unique icons for each alert.
- Plots of the patient's pulse, O_2 sat, and blood pressure as trend lines.
- The ability for the medic to individually customize thresholds that control alerts in the detection algorithm for each patient.

Mapping Capabilities

- An outdoor overhead imagery map with GPS coordinates plotted representing the locations of all patients and medics.
- An Indoor map of auxiliary care centers with coordinates plotted representing the locations of all patients and medics.

Figure 8 Java GUI

Paramedics have a hands-on mentality, and prefer to use their fingers, not a stylus, to navigate the touch-screen GUI. Buttons on the GUI must be large enough that medics can press with their fingers. The GUI also takes into consideration the stress a medic is under, so when they request to make any extreme changes in the GUI, like turning off the alerts for a patient, the GUI should request confirmation. This prevents medics from accidentally disregarding a patient. Lastly, pop-up alerts are difficult to manage when the number of alerts increases.

- **Vital Signs Monitoring**

An algorithm was developed to analyze the vital sign readings received from the patients' sensors, Table 1. When the algorithm detects one of the follow patient conditions, an alert is shown on the GUI:

Table 1 Alert Detection Parameters

Detected Condition	Algorithm	Comments
▪ No Pulse	Pulse = 0	Pulseox reads zero for > 3 *sec*
▪ Bradycardia	Pulse < 40 bpm	an abnormally low pulse
▪ Tachycardia	Pulse > 150 bpm	abnormally high pulse
▪ Onset	$Pulse - Pulse_{baseline} > 19\%$	difference between the most recent beats
▪ Stability	$\frac{\Delta Pulse}{16 samples} > 15\%$	
▪ Low O_2 sat	$O_2 sat - O_2 sat_{baseline} > 5\%$	compares the current readings to the baseline reading for the patient.
▪ Abnormal systolic or diastolic BP	$BP_{systolic} > 90\%$, $BP_{systolic} < 10\%$ $BP_{diastolic} > 90\%$, $BP_{diastolic} < 10\%$	percentages determined by height
▪ MAP change	$MAP = \frac{2 * BP_{diastolic} + BP_{systolic}}{3 * BP_{diastolic}}$ $MAP - MAP_{baseline} > 35\%$	If the mean arterial pressure MAP changes by more than 35% from the baseline for the patient, an alert is triggered.
▪ Pulse pressure change	$BP_{pulse} = BP_{systolic} - BP_{diastolic}$ $BP_{pulse} - BP_{baseline} > 80mmHg$ $BP_{pulse} - BP_{baseline} < 20mmHg$	A change of more than six mmHg from the baseline for the patient, or if it exceeds 80 mmHg or falls below 20 mmHg, the patient may have a serious injury and an alert is triggered.

The analysis algorithm processes patient data. The algorithms were designed to limit the amount of analysis that has to be performed on each piece of data. As soon as any alert is triggered by the detection algorithms, the algorithm breaks out of the structure, freeing memory that can be used for other operations. The alarms triggered by these algorithms are show in two places on the GUI: above the graph of the vital signs and in a summarized list of alerts on the left.

- **Outdoor Location Tracking**

The interface has the ability to display maps and plot the exact location of patients and medics on the maps. The GUI finds the map from a stored database of satellite imagery. Medic locations are indicated by small red crosses on the map. Patient locations are indicated by a "P" and their patient ID number. In addition, patient icons are color-coded according to their triage color.

- **Indoor Location Tracking**

The second type of map that can be used in this UI is an indoor location map. As noted, the indoor location map uses a system known as MoteTrac, another open source project at Harvard University, to determine where a person is located inside buildings. Before MoteTrac can be used, beacon motes must be pre-installed on the walls of the building. The MoteTrac software analyzes the signal strength from each beacon to triangulate the position. We instrumented a floor of one of our buildings at APL with MoteTrac, and were successful in tracking the location of a collection of motes in real time. However, additional further field testing was not promising so the technology was not made an operational component of the testbed.

5. SURVEILLANCE AND INCIDENT REPORTING PDA (SIRP)

Victims can be stuck at the disaster scene for a considerable length of time while ambulances struggle through the traffic and chaos surrounding a mass casualty incident. Patients, in this situation, need to identified and treated at the scene. Current paper-based systems are inadequate to provide the type of registration and health condition tracking, provided in a hospital emergency department, in a pre-hospital setting. This can be accomplished with mote vital sign sensors and the Surveillance and Incident Reporting PDA (SIRP). SIRP was designed to capture information typically recorded by responders on clipboards or paper triage tags and transmit the data instantaneously to the rest of the emergency response community. AID-N designed SIRP to enhance the quality of the data, as well as the collection process itself, without distracting responders from their primary duty of caring for the patients.

The goals for the handheld SIRP PDA are to:

1) Replicate the secondary triage charts used by responders today to make the interface as familiar as possible
2) Take into account the limited text entry capabilities of the PDA, make “smart choices” and automated field population available wherever possible
3) Use GPS receivers to track the location of personnel and patients, as well as to communicate geographical data about the scene to personnel
4) Use integrated cameras to augment charts with visual data about patients
5) Prove the efficacy of a patient-carried medical record in aiding emergency care
6) Provide consistent usability despite likely network connectivity disruptions

Both a web-based version of the software as well as a heavy-client version of the PDA software was developed to allow responders from neighboring jurisdictions to interact with the AID-N system without having to have software pre-installed on a PDA. This “lite” version does not have the full capabilities of the heavy-client, but is available to any PDA or smartphone running Pocket IE 2003 or later that may be carried by new EMS responders coming on the scene

Implementation

The primary version of SIRP is a heavy client for full integration with portable devices designed to improve the efficiency of the following first responder tasks.

Secondary Triage

The SIRP secondary triage forms provide detailed information about a patient’s condition that go beyond the initial 30 second START (Simple Triage and Rapid Treatment) procedure. This information is later provided to the nurse when the patient is transported to a hospital. SIRP replicated the charts in a GUI form on the PDA. To meet the goal of speedy text entry, free text areas were replaced with choices which could be selected with a single tap on a radio button or check box. Rather than typing an age, a medic would simply tap buttons labeled “infant,” “child,” or “adult.” Similar selections were provided for the patient’s level of consciousness and chief complaint, and a drop down box contained a list of contaminants to choose from if the patient required decontamination.

In order to maintain consistency with the current forms, close attention was paid to terminology, which was especially difficult for two reasons: first because the PDA provided limited screen space for long terms and second because terminology varies from one jurisdiction to another. Taxonomy in healthcare is a science in its own right, so instead of attempting to solve the problem of conflicting and difficult terminology, the system was implemented with an open framework to allow the text to be provided from a configuration file or web service so that the client could specify the terms to be used. This also allows the forms to be translated to other languages for international use.

For particular injuries, especially burns and lesions, the physician at the receiving hospital must look at the injury in order to diagnose it and gather the resources to properly treat the patient. Once AID-N allows the physician to learn about incoming patients before they have even left the disaster scene, it becomes enormously valuable to have photos of injuries accompany the patient record. To that end, SIRP included a camera, integrated with the SIRP software to allow photos to be taken of injuries and automatically uploaded to the server. These photos could also be annotated by the responder to indicate where the injury is and provide a description of the photo.

Patient Identification

Patient identification is necessary for hospitals because it allows them to connect with the patient’s family and to ensure that the hospital is reimbursed by the patient’s insurance. If a patient history is included, the information can be used to avoid allergic reactions during treatment and to account for other risks. Unfortunately this information is almost impossible to obtain if the patient cannot provide it directly, and so many organizations have begun to investigate solutions for patient-carried medical records. To prove the efficacy of these records within the AID-N system, SIRP assumes a particular implementation of a solution – information encoded in a 2-D barcode on the driver’s license – and provides an interface for that solution. With SIRP, providers could use a Bluetooth-enabled barcode scanner to rapidly retrieve a patient’s name, age, gender, address, phone number, next of kin contact information, medications, pre-existing conditions, and allergies. In the case where a patient did not have a driver’s license, the information could be entered manually, but it would be time-consuming.

Here again, the integrated camera was used to capture images of each patient’s face for later identification amongst other patients. This could be used by medics assigned to pick up the patient for transport or to find a patient whose vital signs indicated a deteriorating condition. The photo would also be useful for families attempting to locate their loved ones and especially children. Parents could identify their children by a photo and an EMS worker would be able to direct them to the hospital where they were transported. Future work could allow searches based on the features of the image such as hair color, eye color, clothes worn, or by scanning an image of the child and doing facial recognition.

Both versions are integrated into the AID-N network to provide patient and scene information to the emergency response community.

Figure 9. Sample SIRP Screens

6. HEADS UP DISPLAY AND CAMERA SYSTEM

During a mass casualty situation there is often a need to establish a secondary treatment area or temporary auxiliary care center near the disaster scene to shelter and care for victims while waiting for transport and for some to be treated and released. As previously described the SIRP PDA was developed to collect pre-hospital patient records patients and is expected to be a valuable tool for these ad hoc treatment facilities. The Heads-Up Display and Camera System (HDCS) is another, which was developed to be used for physician-first responder mentoring. It consists of the following parts and as shown in Figure 10:

1. Clear glasses that have two attachments:
   - A small video camera that attaches to one temple.
   - A small display that attaches to another temple and projects the same image that is received by the camera through the glasses, directly onto one eye.

2. A Belt Pack containing the transmitter and battery that sends the video signal to a local computer in the ambulance or elsewhere at the scene.

3. A computer and a receiver in the ambulance, triage location or elsewhere at the scene, that receives the video signal from the first responder and transmits it to an Internet site so that it can be viewed by a physician located outside of the mass casualty scene.

The Heads-Up Display and Camera System allows real-time video information to be sent to medical staffs who are not on the scene (remote staff) so that they can assist the staff on the scene (local staff) with diagnosis, triage and treatment.

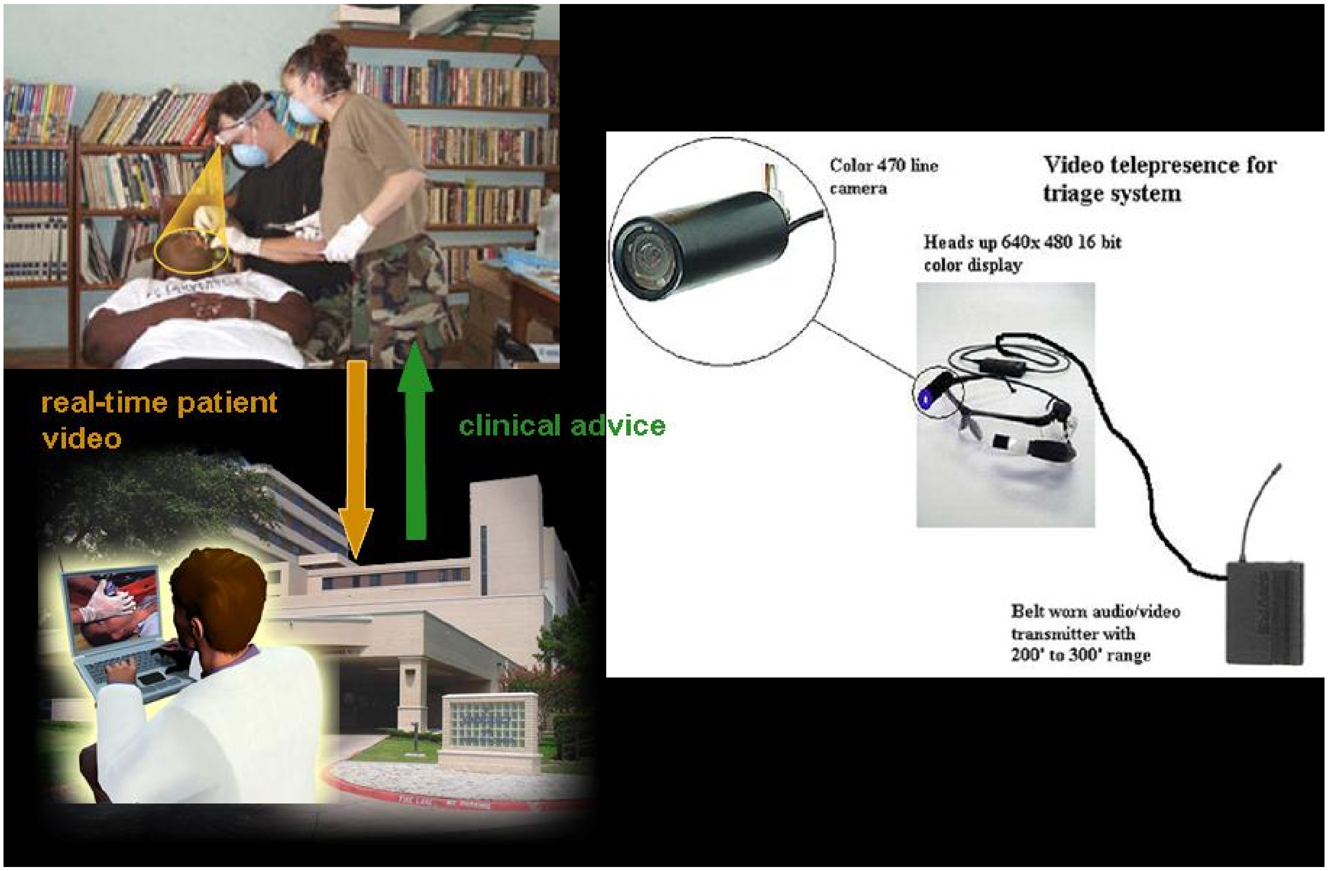

Figure 10. Heads up display unit

The HDCS was evaluated by the ECRI Institute (Ref. 1). It was decided that web cameras could be used for telementoring purposes instead of the HDCS with the advantages of being all digital and IP-based, as well as, being easier to maintain. Web cams, in general, would have to be mounted or clamped instead of being worn by the paramedic. Therefore they would have to be pointed in a static direction and retrained as needed instead of the HDCS which is worn by the paramedic and points wherever he looks. However, for this function either would have the advantage depending on the situation.

7. TEST AND EVALUATION

The demonstration, test and evaluation of the AID-N system were a continuing process throughout the term of the project involving the developers, users, and independent evaluators. This included: evaluated by the user community during its development, specific components have been evaluated by the ECRI Institute, numerous small scale demonstrations were given throughout the project to various government organizations and other interested parties, a full scale technology demonstration was given to the sponsor and the emergency response technology developers on June 23, 2006 at JHU/APL, and the system was demonstrated and evaluated at a Mass Casualty Incident Field Test on August 5, 2006 at Montgomery Blair High School in Maryland.

The prototypes and feature improvements were reviewed by the following EMS groups:

- 3 paramedics at the annual Fire, Rescue, and EMS Expo held at the Baltimore Convention Center (July 27-29, 2005)
- 3 paramedics at the APL local fire department (August 02, 2005)
- 3 paramedics and 5 first responders at the Baltimore Washington International Airport Fire and Rescue Department (August 04, 2005)
- 8 paramedics, 2 platoon chiefs, and 3 captains at the Arlington Fire and Rescue (Sep 27 2005)

Surveys were created to gather user feedback, which were used to improve our design.

7.1 Mass Casualty Exercise Field Test – August 5, 2006

The field test exercise is a prospective case controlled analysis of patient assessment, logistics, and team communication in a simulated mass casualty event where two teams of EMS providers care for patients. One team of providers used traditional vital sign monitoring and communication devices while the other team used advanced technologies including wireless vital sign monitors and internet technologies. The goal of this study was to determine if wireless monitoring of patient vital signs during a simulated mass casualty event would improve the ability of medical providers to obtain essential patient information and continuously transmit the data to EMS officers, public health officials and destination hospitals as compared to traditional methods.

To collect data on the response process, we conducted observations and interviews before, during, and after the drill.

The scenario simulated a multi-car traffic accident, and took place at a busy intersection in Silver Spring, Maryland, on August 5, 2006. The event brought together responders from multiple EMS departments in Montgomery County, Maryland. The event assumed a traffic accident caused by an overpass collapse with over 100 wounded victims. The surge of patients overflowed all hospitals within the 15 mile radius of the accident. The drill focused on a subset of the total patients, and involved 20 wounded victims from a single bus, separated into a control group and an experimental group of 10 patients each. The 20 volunteer victims were provided by the Red Cross. 15 trained EMS personnel were provided by Montgomery County Fire and Rescue. Some of the patients were transported to Suburban Hospital, a level-one trauma center. Other patients that required less immediate treatment, but could not be sent to the hospital because of the overflow situation, were transferred to the nearby Montgomery Blair High School, which was set up as an ad hoc auxiliary care center and was staffed by the EMS personnel from the scene.

The responders were separated into two teams, a paper team which used traditional EMS equipment, and an electronic team which used AID-N technologies. Each team was comprised of identical command structure with 7 personnel: incident commander, triage officer, treatment officer, transport officer, and 3 responders. Due to resource constraints, a single vehicle was used to carry patients from both teams to the hospital. A central commander was responsible for keeping track of the ongoing progress of both teams.

The disaster was staged with a bus, carrying 20 patients and a bus driver. The paper team patients sat at the front of the bus, while the electronic team patients sat at the back of the bus. All patients wore, on their neck, a lanyard with 10 note cards, which contained a scripted description of their vital signs. The front of each note card was labeled with the patient's age, gender, heart rate, O2 sat, blood pressure, and chief complaint. Responders were asked to triage and treat the patients based upon information shown on the note cards. The back of each note card contained instructions for the patient on when to flip to the next note card. Each patient received a unique set of note cards and flipped through their note cards as instructed. Each stack of note cards simulated the physiological trends of a potential patient. The physiological trend values were scripted by an experienced paramedic. The paper and electronic team received identical sets of note cards. The medic used their discretion to triage patients to a priority level based on the information on the note card.

Both response teams stood approximately 50 meters from the bus. At the start of the event, an ambulance siren signaled both teams to approach the bus and initiate triage of patients on the bus. Upon initial triage, paper and electronic team patients walked through the front and back doors of the bus, respectively, to the nearby treatment/waiting area. Patients were held at the scene for 30 minutes before transport, during which time some patients would experience secondary injuries, as scripted on their note cards.

Two of the ten patients in each group were scripted to experience significant secondary injuries during the event. The first patient would experience a heart attack while waiting for the ambulance at the scene. The second patient would experience a heart attack while waiting in the auxiliary care center.

The patients were required to be re-triaged/assessed until they reached the hospital or the end of the drill. Table 2 records the total number of times each patient was recorded as being triaged (initial triage and re-triage). While the results are subject to observer error (as seen with patient 6B, who was never recorded as being triaged), team A was able to triage each patient a mean of 7.8 (SD +/- 2.8) times during the drill, while team B was only able to triage each patient a mean of 2.9 (SD +/- 1.8) times. Team A's proportionally smaller standard deviation shows that this treatment level was more evenly distributed among patients. In other words, one or two needy patients did not prevent the other patients from being looked after.

Table 2. Patient Triage Counts

Patient Triage Counts During the Drill		
	Team A	Team B
Patient 1	7	5
Patient 2	7	4
Patient 3	7	3
Patient 4	12	4
Patient 5	8	1
Patient 6	10	0
Patient 7	4	1
Patient 8	7	5
Patient 9	4	2
Patient 10	12	2
Unspecified	0	2
Totals:	**78**	**29**
Mean:	**7.8**	**2.9**
Standard Deviation:	**2.8**	**1.8**

Seven of the EMS personnel agreed to complete a questionnaire immediately after the test to determine their acceptance of the technology. The results are compiled in Table 2. The response to the question was a Likert scale with 1 being dissatisfied and 5 being highly satisfied. Some did not answer all the questions giving a low number of samples for a number of the questions.

	Treatment Officer	Incident Command	Ambulance / Triage Officer	Transport Officer	Triage/ Treatment Personnel 1	Triage/ Treatment Personnel 2	Ambulance /Treatment Personnel	**Mean**	**SD**	**n**
I would use electronic triage tags over paper triage tags from now on	5	4	4	n/a	4	1	5	3.83	1.47	6
This system would help improve the survival rae or patients (by staying within the Golden Hour)	3	n/a	4	n/a	4	1	4	3.20	1.30	5
The system would increase the number of patients I can handle	5	1	5	4	2	1	4	3.14	1.77	7
The system would facilitate decisions regarding the order in which patients are transported	5	5	5	4	1	1	4	3.57	1.81	7
This system helped me work more efficiently with large numbers of patients	5	4	5	4	1	1	5	3.57	1.81	7
This sytem was a more efficient way to keep track of triage counts	5	5	5	4	5	5	5	4.86	0.38	7
This system was a more efficient way to track patient locations prior to transport	5	2	n/a	2	5	n/a	n/a	3.50	1.73	4
This system was a more efficient way to track patient locations after transport	n/a	n/a	n/a	3	1	n/a	n/a	2.00	1.41	2
This system was a more efficient way to track which ambulances are used to transport specific patients	n/a	4	n/a	4	3	n/a	4	3.75	0.50	4
This system was a more efficient way to monitor patients in the waiting area	5	1	4	1	5	1	4	3.00	1.91	7
This system was a more efficient way to communicate with: Incident Commander	2	n/a	5	4	n/a	empty	1	3.00	1.58	4
This system was a more efficient way to communicate with: Triage Officer	5	2	n/a	4	n/a	empty	1	3.00	1.83	4
This system was a more efficient way to communicate with: Treatment Officer	n/a	2	n/a	4	n/a	empty	4	3.33	1.15	3
This system was a more efficient way to communicate with: Transport Officer	5	2	5	3	n/a	empty	4	3.80	1.30	5
I received sufficient training on this equipment:	empty	5	3	2	2	empty	5	3.40	1.52	5
With more training, I would be more likely to endorse this equipment	empty	n/a	4	4	4	empty	5	4.25	0.50	4
It's difficult to rate the effectiveness of this equipment given the amount of training I received today	empty	n/a	2	n/a	4	empty	n/a	3.00	1.41	2

Table 3. August 5, 2006 Questionnaire Data

The test proved that:

- EMS personnel, hospital emergency department administrators, and public health officers can view patient and disaster scene information in real time with an improved understanding of the situation.
- Paramedics responsible for the patients with electronic tags were able reassess the patient condition (retriage) more frequently, implying a higher quality of patient care.
- Electronically recording the patient data for viewing by all required users reduced the number of radio/phone calls; the phone calls that were made were mostly used to double check on data as opposed to critical information communication.

The surveys indicate that there are still barriers to adopting the technology by first responders including:

- Limited training: technologies must be used every day if they are to be successfully used in a critical disaster.
- Technologies can provide verification. They can also discover mistakes at a specific point of the disaster response process when the technology data differs from the

manually reported data. This is a useful indicator of any mistakes that may happen in the ongoing disaster. However, this introduces a barrier because it's uncomfortable for the responders to be watched over by the technology, and their actions are being double checked.

- Lack of trust in the technology: This is something novel, they don't trust what they see. They need to get used to this type of thing, there is plenty of work ahead in disaster training. There is a need to trust that the technology is implemented correctly in a large scale deployment.
- New technologies warrant new methodologies for emergency response. We cannot expect the responders to operate with the new technologies using the response protocols that were designed for their current equipment. There is plenty of work ahead in planning a new response protocol that allows responders to operate efficiently with the new technologies.

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