1-1-1998

A Study Of Army Medical Treatment Methodology & Medical Simulation Related Products: Final Technical Report

Sumeet Rajput

INSTITUTE FOR SIMULATION & TRAINING

Contract Number: N61339-98-M-0174
Organization: STRICOM
March 23, 1998

A Study of Army Medical Treatment Methodology & Medical Simulation Related Products

Final Technical Report

Authors: Sumeet Rajput & Chun-Chin Fang

University of Central Florida

Institute for Simulation and Training
3280 Progress Drive
Orlando FL 32826

University of Central Florida
Division of Sponsored Research

IST-TR-98-03

N 96

INSTITUTE FOR SIMULATION AND TRAINING

A Study of Army Medical Treatment Methodology & Medical Simulation Related Products

Final Technical Report

IST-TR-98-03
March 23, 1998

Prepared For:
STRICOM
Contract Number N61339-98-M-0174

Reviewed by:

Brian Goldiez

Prepared by:

Sumeet Rajput

Institute for Simulation and Training • 3280 Progress Drive • Orlando, Florida 32826
University of Central Florida • Office of Research & Graduate Studies

Final Technical Report
A Study of Army Medical Treatment Methodology & Medical Simulation Related Products

IST-TR-98-03
Contract N61339-97K-009
March 23, 1998

INSTITUTE for SIMULATION & TRAINING

Sumeet Rajput and Chun-Chin Fang

Executive Summary

The Combat Trauma Patient Simulator (CTPS) project is a research effort in which a dual purpose training and test and evaluation (T&E) system is being developed and prototyped. The prototype system is intended to realistically simulate emergency medical treatment. The CTPS project has two primary goals. First, provide improved training for Army medical personnel and improved care for combat patients. Second, provide an enhanced mechanism for analysis and T&E of issues in casualty medical treatment.

The Phase 1 effort concluded in December 1997 and the next phase is expected to begin in the first quarter of 1998. Before starting the next phase, IST believes that an effort must be made to provide a firm basis for determining what areas of casualty care Phase 1 addresses, what areas need to be addressed, and what areas are covered by existing products. This study was proposed to the US Army's Simulation Training and Instrumentation Command and was carried out subsequently. This report details the findings. The primary purpose of the study is to:

- Define the methodology the Army employs to provide combat casualty care and
- Identify simulation components that can be adapted to model this methodology.

This report is divided into three parts. In the first part we present the Army's methodology for treating combat casualties. We identify the levels of combat care from which a treatment methodology is described. We relate the architecture of the CTPS system to this methodology and show how the simulation components in the CTPS system correspond to the levels of combat care.

The second part of the report presents the medical simulation related products. These products fall into two categories: 1) hardware-based simulation products that are typically human patient simulators, driven by computer models of human physiology and pharmacology and allow "hands on" training for medical personnel; 2) software-based simulation products that are also driven by computer models of human physiology and pharmacology but display their output on a computer screen.

The third and final part of the report examines how the medical simulation products that were identified can be adapted to enhance the capability of the CTPS system. We indicate at which level of care a product would be most useful.

Table of Contents

Table of Figures

1. Introduction

This report is a deliverable under STRICOM contract N61339-98-M-0174. It details the research undertaken between phases 1 and 2 of the Combat Trauma Patient Simulator program (CTPS), a long term research effort in which a dual purpose training and test and evaluation (T&E) system that realistically simulates emergency medical treatment situations is being developed and prototyped.

1.1 Background

The Institute for Simulation and Training (IST) has been leading a multi-contractor team conducting research and prototyping activity for the US Army's Simulation, Training, and Instrumentation Command (STRICOM) under contract N61339-97-K-0009. The research effort has been oriented toward creating a CTPS system. The goal of the research effort is to demonstrate the feasibility of using simulation technology to reduce the deaths due to wounds in combat. This goal will be accomplished by inserting the medical component into various types of live fire simulation exercises. Live, virtual, and constructive simulations can be accommodated in the CTPS architecture. Additionally, the CTPS can accommodate most parts of the medical treatment of casualties from initial diagnosis and treatment in the field to treatment in an emergency room such as a Mobile Army Surgical Hospital (MASH).

During Phase 1 of this project, the IST research team interconnected three simulation components [1]. Two of the CTPS system components were existing simulators: the Human Patient Simulator (HPS), developed by Medical Education Technologies, Inc. (METI); and the Electronic Casualty Card (ECC), which is used in SAWE/MILES force-on-force military training exercises, developed by Lockheed Martin Electro Optics Systems (LMEOS). These simulators were augmented for use in the CTPS system. METI customized the HPS for use in the CTPS system to simulate combat trauma patients. Lockheed Martin created a database translator to convert the information output by the ECC into a format understandable by the CTPS system. The third simulation component of the CTPS system, the Patient Simulator, is a software simulation of a patient prototyped by IST. The PatSim queues patients in the system, simulating them in software until they can be transferred to an HPS. PatSim functionally interfaces the HPS to the ECC, allowing them to work together within the CTPS.

At the close of Phase I of the project, an initial prototype version of the CTPS system exists. A credible data flow has been established between the ECC, the HPS, and PatSim, and the system has been demonstrated with various scenarios to verify its functionality. Casualties generated on the ECC are transferred to PatSim to await medical treatment, then to an available HPS for medical intervention. In sum, the CTPS provides a simulation capability for medical training and analysis that is not currently achievable with other systems.

The Phase 1 effort concluded in December 1997 and a proposal for a Phase 2 effort was recently submitted to STRICOM for consideration. The Phase 2 effort is expected to begin in the first quarter of 1998.

1.2 Statement of Objectives

Before work on the Phase 2 effort begins, IST recommended a study be conducted oriented to clarifying two issues:

- Describing the methodology employed by the Army for combat casualty care and
- Identifying where existing simulation components can be used or adapted to model this methodology.

IST believes this effort was necessary to provide a firm basis for determining what areas of casualty care Phase 1 addresses, what areas need to be addressed, and what areas are covered by existing products. This effort is significant in focusing future effort in the correct direction. This study was proposed to STRICOM and was carried out subsequently. Specifically, IST proposed to:

- Review material from recent conferences related to medical treatment of casualties and equipment which may be available to simulate such treatment,
- Search the World Wide Web for relevant medical simulation products,
- Contact vendors and agencies which may produce simulation related products or be involved in defining military casualty care, and
- Study material available from the Army on handling combat casualties.

2. Army Medical Treatment Domain Analysis

2.1 Levels of Combat Care

In the Army, combat care is divided into five levels. Each level designates the roles of the health care professionals. These roles are defined in the appropriate Army publications such as Field Manuals, Soldier's Manuals, and Army Training and Evaluation Program (ARTEP) Manuals [2] [3]. The roles are also dependent on where a medical treatment facility is placed on the battlefield. This decision is made according to the Battlefield Operating System that is appropriate for the battle space. The battle space is itself determined after taking into account the mission, enemy, terrain, troops, and time available (METT-T).

At each level of care two activities occur. First, the patient's condition is diagnosed and second, the appropriate treatment is applied. The resources available determine diagnosis and treatment at each level and include the materiel, personnel, and training levels. A patient "moves" up though the levels if lower levels cannot provide sufficient care to allow a patient to Return To Duty (RTD). A patient's movement through the levels of care is shown in Figure 1:

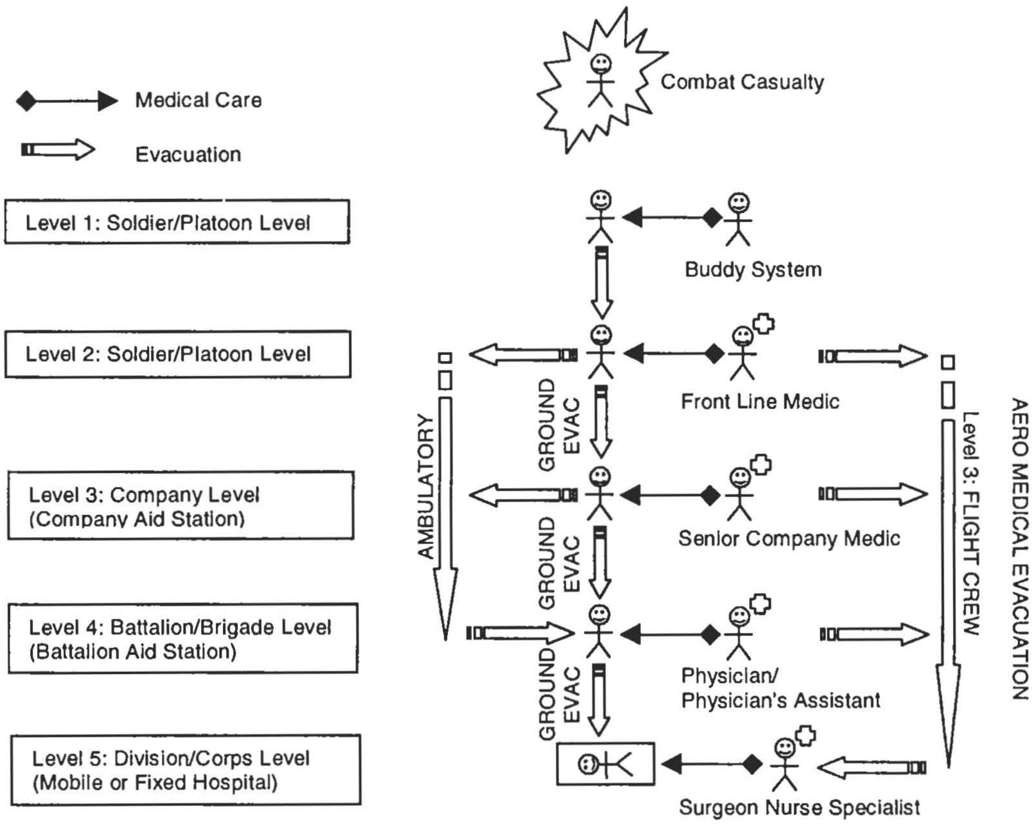

Figure 1: Levels of Medical Treatment.

The first person to give care to a combat casualty is usually another soldier. This level of care takes place at the Soldier/Platoon level and is referred to as the "Buddy System." The soldiers provide basic first aid and are trained to:

- clear the casualty's airway,
- stop bleeding,
- protect the wound, and
- treat for shock.

A Front Line Medic then treats the wounded soldier at the Soldier/Platoon level. This medic provides advanced first aid and Cardio Pulmonary Resuscitation (CPR). The medic provides an initial diagnosis, administers limited pharmacological treatment, and prepares the soldier for evacuation.

A Senior Company Medic provides level 3 (Company level) care at the Company Aid Station (CAS). This medic has limited capability and more treatment options than the

Front Line Medic has at the Soldier/Platoon level. Ground evacuation (GROUND EVAC in Figure 1), ambulances (AMBULATORY in Figure 1), and air evacuation (AERO MEDICAL EVACUATION in Figure 1) teams are also capable of providing level 3 care while a soldier is being evacuated. The ambulances and aero medical evacuation teams are equipped with life support equipment and a senior medic.

A physician or physician's assistant provides level 4 (Battalion/Brigade level) care at a Battalion Aid Station (BAS). The BAS has limited trauma capability.

Level 5 is the final level of medical care. This level of care is given at a Mobile Army Surgical Hospital (MASH) that is staffed with surgeons, specialists, and nurses who have special treatment capabilities.

Based on the soldier's condition any one of three evacuation methods can be used. Ground evacuation (GROUND EVAC) provides a link between adjacent levels of care and is the most basic form of evacuation. Ambulances (AMBULATORY) connect levels 2, 3, and 4 and can transcend levels; e.g., a level 2 casualty can be evacuated to a level 4 treatment facility without going through level 3. While the casualty is in an ambulance it is given level 3 care. Medical helicopters (AERO MEDICAL EVACUATION) provide the fastest method of evacuation. They connect the MASH with other (lower) levels. They can also transcend levels so that a lower level casualty can be directly evacuated to the MASH without going through intermediate levels.

2.2 Replication of Health Service Support in CTPS

In Phase 1, a basic CTPS architecture was developed. Briefly, the architecture can be abstracted to reveal 3 key components:

- a casualty generating module,
- a module which simulates a patient's physiology in software, and
- a module which provides a hardware and software simulation of the patient.

The first key component in the CTPS system is LMEOS's ECC that is used to generate combat trauma casualties for insertion into the CTPS system. The ECC is linked to other components in the CTPS system through the ECC Interface. The PatSim currently comprises the second key component of the CTPS. The casualties are "held" in the Patient Simulator (PatSim) where their physiology is continuously updated until an HPS is available. The third key component is METI's HPS that allows a human medic to administer care to the patient. The HPS is linked to other CTPS components through the HPS Interface. Limited treatment to casualties is also possible through the ECC.

The CTPS system can be (re)interpreted in terms of the levels of medical care described in Section 2.1.

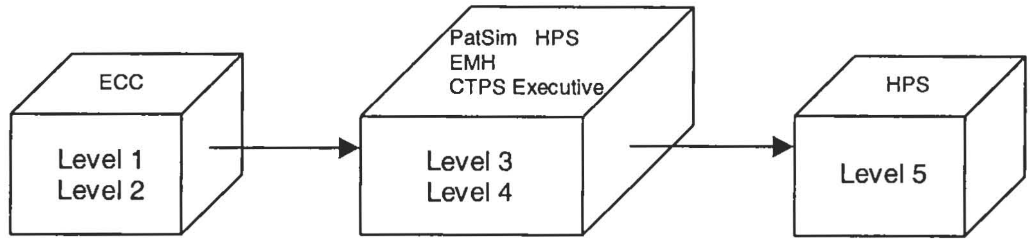

Figure 2: CTPS system supports levels of medical care.

Figure 2 shows the components of the CTPS system and one of several possible relations to the levels of medical care as used in the Army. The ECC's main function is to generate casualties and to identify the casualty type. Basic medical care can also be given through a Medical Control Device (MCD) that accompanies the ECC; for example, the MCD can be used to stop a patient's wound from bleeding. The ECC also contains a mechanism to transfer the casualty to other CTPS components which is akin to evacuation in the real battlefield. These functions, casualty initiation, basic medical care, and casualty evacuation correspond to levels 1 and 2 in the Army's medical treatment methodology.

The PatSim simulates a patient's physiology in software. Phase 2 enhancements to the CTPS system will include the implementation of an *Expedient Medic Heuristic* (EMH) and a *CTPS Executive*. The EMH will be an implementation of an automated medic that will be used to treat patients when a human medic or physician is unavailable, e.g., when there are too many patients or during transport. The EMH would attempt to model the actions of a real medic. The CTPS Executive is software that will be used to coordinate the actions of other simulation components in the CTPS system. In addition, it will be able to handle patient evacuation using a stochastic estimation technique that simulates the movement of patients in the battlefield. The HPS can also be used at this level to provide trauma handling capability typically available at the CAS and BAS.

The combination of PatSim, EMH, CTPS Executive, and HPS will simulate the care provided at levels 3 and 4 in the Army's medical treatment methodology. For example, a patient, simulated by the PatSim, will be given limited trauma care (levels 3 and 4) by the EMH or by a human Medic through the HPS, and can be evacuated through the mechanism provided by the CTPS Executive. A version of the HPS, called the Pre-Hospital Simulator, will shortly be available from METI. This system is a toned-down version of the HPS and will be able to simulate a limited set of trauma types as compared to the number supported by the HPS. It is conceivable that this system will be used instead of the full-fledged HPS at levels 3 and 4 to provide the limited trauma handling capability required at those levels.

The HPS can also provide advanced trauma handling capability and will be used to provide the same level of care as level 5 in the Army's medical treatment methodology. Thus, the CTPS will be able to replicate the levels of medical care in the Army.

3. Medical Simulation Related Products Market Survey

Two types of medical simulation products were studied. Hardware-based simulation products allow realistic human interaction, such as by touch and feel; for example, an HPS. Software simulation products allow simulation of a patient's physiology and pharmacological treatment through a computer model and display the results on a computer screen. A patient can be "cared for" only through a graphical user interface. Sections 3.1 and 3.2 discuss hardware and software-based medical simulation products that can be adapted to function in the CTPS system. Several other products were also studied but were deemed unsuitable for CTPS use. These are described in Appendix 7.2.

3.1 Hardware-based Medical Simulation Products

1. The Leiden Anesthesia Simulator (LAS) [4], which is not available for commercial use, creates a training environment for anesthetists. It makes use of a standard anesthesia machine and monitoring devices. A modified commercially available mannequin attached to an electro-mechanical lung machine represents a simulated patient. A physiological and pharmacological model that runs on an IBM personal computer controls the patient's simulated parameters.

2. The UltraSim ultrasound simulator (UltraSim) [5] is a commercially available system that allows students to practice sonographic exams while viewing real sonographic images. It includes a mid-torso mannequin designed for OB/GYN and abdominal scans and another one for upper-torso scans.

3. The Eagle Patient Simulator (Eagle) [6] is a commercially available system that consists of a full body mannequin, operator station, interface cart housing the electronic and pneumatic drive equipment, and software describing patient physiology. It features:

    - a rugged, portable system which can be serviced, if necessary, by any hospital equipment engineering staff;
    - thirty simulated cardiovascular, pulmonary, and metabolic events;
    - simulated physiological reactions to 85 drugs, along with their medically-established side effects;
    - scenario generation by the individual instructor/operator; and
    - a support and maintenance program that can be tailored to the user's needs.

3.2 Software-based Medical Simulation Products

1. BODY Simulation (BODY) [7] is a commercially available interactive multimedia model driven tool that models the physiological and pharmacological parameters of a patient. It is being used by hospitals, universities, and medical device manufacturers for education and training.

2. The Sim*Bio*Sys [8] software is a commercially available real-time physiology simulator. It is based on 150 differential equations and has over 1000 physiological parameters. The underlying models include a heart, lungs, and kidneys; these are coupled to a vascular system and peripheral organs, all of which are coordinated by the central nervous system.

3. Anesthesia Simulator Consultant (ASC) [9] is a commercially available real-time graphical simulator that reproduces the anesthesia environment on a computer screen. It includes several anesthesia scenarios such as myocardial ischemia, anaphylaxis, malignant hyperthermia, and cardiac arrest. It is run by mathematical models of physiology and pharmacology.

4. Quantitative Circulatory Physiology (QCP) [10] is a commercially available computer program that simulates the dynamic interaction of integrative physiology. Elements of respiratory, circulatory, endocrine, neural, and renal physiology have been combined to produce a complete model of human physiology. The simulator is based on mathematical descriptions of physiological function and interactions.

5. The Virtual Medical Trainer (VMT) [11] is a commercially available system that allows training of pre-hospital emergency care and is specially suited for multi-trauma patient assessment (i.e., multiple external and internal injuries on a given patient).

6. NBC MedPlanS [12] is a planning tool that can be used for defense planning, contingency planning, and mission planning. It also supports training for medical planners. Users can define a scenario through several parameters such as potential NBC agents, personnel at risk, geographical situation, weather conditions, and vaccination and chemoprophylaxis status. The system then performs a simulation of the attack as defined by the scenario inputs and generates a probable number of casualties and an estimate of injury severity. The system then simulates the treatment of every category of patient. The results generated by the system include:

    - an estimate of medical personnel required,
    - decontamination requirements,
    - bed usage,
    - medical materiel, and
    - medical evacuation places.

4. Use of Medical Simulation Products in CTPS

The medical simulation products identified in Section 3 can be used to simulate medical care at all levels in the Army's medical treatment methodology. Figure 3 shows how these products can be adapted to fit into the CTPS architecture:

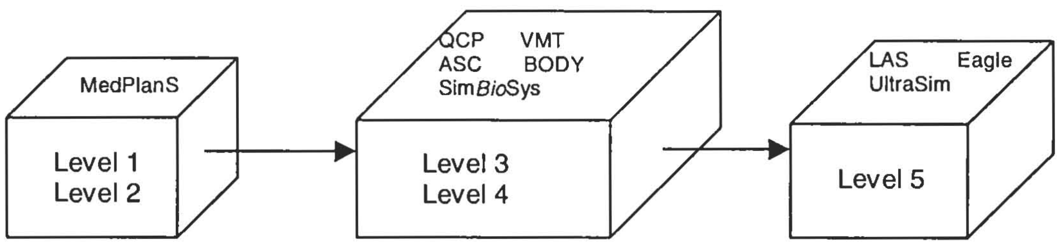

Figure 3: Adapting New Simulation Products.

The MedPlanS software is a useful tool for generating a large number of casualties based on the simulation of an attack. It is advantageous over the ECC because it can generate a large number of casualties at one time as opposed to the ECC that generates them one at a time. The system is flexible and allows a user to modify the casualty estimates. Other information output by the software, such as an estimate of medical personnel required, can be used to efficiently allocate medical personnel to casualties. The program runs on personal computers and can be interfaced to standard office software tools.

The software products identified for use in levels 3 and 4 (see Figure 3) can be adapted for use in many ways. First, the physiological model that underlies one of these products can be extracted to form the core of a more realistic PatSim (a requirement for Phase 2). Second, the pharmacological model can be extracted to build the EMH (also a requirement for Phase 2). An important issue that needs to be resolved is that of data transformation. The casualty data output by the ECC or MedPlanS must be converted into a form suitable for input into the model and the model's output must be converted into a form that can be transmitted to other simulation components in the CTPS system. This development will, for obvious reasons, proceed after contractual agreements would be signed with the owners of the chosen products. IST believes that adapting software rather than developing it in-house will be more cost effective.

LAS and Eagle's Patient Simulator (Section 3.1) are counterparts to METI's HPS and can be used instead at level 5. Ultrasim, connected to other components in the CTPS system via the High Level Architecture (HLA), provides a new capability in that it allows medics to perform sonographic exams on a mannequin while viewing real sonographic images. This simulator can be used in level 5 *in conjunction* with an HPS – a patient's physiology can be represented by the HPS while the sonographic exams on the same patient can be performed using Ultrasim. This dual mode feature will significantly enhance the CTPS system and make it more realistic if sonograms are, in fact, used by the military in the field.

5. Conclusions

At the conclusion of Phase 1 of the CTPS program, IST and its team members have shown connectivity between three medical simulation devices, the ECC, PatSim, and HPS. A credible data flow has been established between the ECC, the HPS, and PatSim, and the system has been demonstrated with various scenarios to verify its functionality. Casualties generated on the ECC are transferred to PatSim to await medical treatment, then to an available HPS for medical intervention.

After examining the literature, a better understanding of the Army's medical treatment methodology has emerged. The Army's medical treatment is divided into five levels. As one advances up the levels the care become more specialized. Level 1 and 2 care provides basic first aid and treatment for stabilizing a patient's condition. Level 3 and 4 take place in the Company and Battalion Aid Station respectively where better trained medical personnel and equipment are available. Level 5 is the highest level of care and is provided by a MASH staffed with surgeons and specialists.

IST examined several medical simulation products. These can be divided into two categories. Hardware-based products typically include a mannequin that represents a patient to whom care must be administered. These products allow a "hands on" experience in the sense that a medical personnel can "feel" the patient and provide care in a fashion similar to that for a real person. Computer models of human physiology and pharmacology control these products. Software-based products are also run by computer models of human physiology and pharmacology but display their output on a computer screen. Care is provided to a simulated patient typically through a graphical user interface.

IST has indicated how the CTPS architecture can be used to simulate the Army's levels of medical care. The simulation components developed in Phase 1 and those proposed for development in Phase 2 could be arranged to cover the entire spectrum of medical care. Moreover, we have shown how the medical products fit into the CTPS architecture and at what level they will be most useful.

6. References

1. Rajput, S. R., Tu, H. K., Goldiez, B. F., and Petty, M. D. (1997). "Combat Trauma Patient Simulator" IST-CR-97-28, Institute for Simulation and Training, University of Central Florida, Orlando, FL 32826, December 19, 1997.
2. Anton, John J. (1997). "Final Report: CTPS Assessment Plan," Lockheed Martin Information Systems, May 31, 1997.
3. US Army (1991). "Medical Evacuation in a Theater of Operations: Tactics, Techniques, and Procedures," FM 8-10-6, Headquarters: Department of the Army, Washington, DC, October 31, 1991.
4. LAS. "Leiden Anesthesia Simulator," (http://web.inter.NL.net/ncc/Stef.Olofsen.Post/las.htm).
5. UltraSim. Manufactured by MedSim, (http://www.medsim.com/products/products.html).
6. Eagle. Manufactured by Eagle Simulation Inc. (http://www.eaglesim.com/products/patsim/overview.html).
7. BODY Simulation. Made by Advanced Simulation Corporation. (http://www.tminus10.com/body).
8. Sim*Bio*Sys. Made by Critical Concepts Inc. (http://www.laketech.com).
9. ASC. Made by Anesoft Corporation, Issaquah, WA 98027.
10. QCP. Made by Biological Simulators, Inc. (http://www.biosim.com).
11. VMT. Developed at the Research Triangle Institute. (http://www.rti.org/vr/w/vmetsum.html).
12. NBC MedPlanS. Made by ESG. (http://www.esg-gmbh.de).

7. Appendices

7.1 Acronyms

Acronym	Description
ARTEP	Army Training and Evaluation Program
ASC	Anesthesia Simulator Consultant
BAS	Battalion Aid Station
CAS	Company Aid Station
CPR	Cardio Pulmonary Resuscitation
CTPS	Combat Trauma Patient Simulator
ECC	Electronic Casualty Card
EMH	Expedient Medic Heuristic
GROUND EVAC	Ground Evacuation
HLA	High Level Architecture
HPS	Human Patient Simulator
IST	Institute for Simulation and Training
LAS	Leiden Anesthesia Simulator
LMEOS	Lockheed Martin Electro Optics Systems
MASH	Mobile Army Surgical Hospital
MCD	Medical Control Device
METI	Medical Education Technologies, Inc.
METT-T	Mission, Enemy, Terrain, Troops, and Time available
PatSim	Patient Simulator
QCP	Quantitative Circulatory Physiology
RTD	Return To Duty
STRICOM	Simulation Training and Instrumentation Command
T&E	Test and Evaluation
VMT	Virtual Medical Trainer

Table 1: Acronyms.

7.2 Non-Simulation Related Medical Products

IST's analysis revealed several medical products not possessing simulation capability. These products are listed below for completeness:

- Combat Lifesaver course (http://www.ches.edu): The development of this course was sponsored by the National Guard Bureau and the U. S. Army Research Institute.

- Video Teletraining (http://www-dcst.monroe.army-mil): Training offered via video teletraining includes lessons learned at the National Training Center, The combat health support system, Division Medical Operations Center (DMOC)

Level 3, division medical support, and various medical evacuation system subjects.

- Differential Diagnosis (http://www.ches.edu): Consists of 34 lessons delivered via CD-ROM. This training is provided together with other materials to convert a certified, 22-month dental hygiene program into distance learning technologies.

- Training Bulleting Board (http://www.cs.amedd.army.mil): This bulletin board, accessible by modem, contains over 60 computer-based training products, numerous digitally stored documents, and lists of slides, video tapes, and other training support media.

- Computer Aided Response Expert for Medical Emergency Decisions (CAREMED) (POC: Ms. Lynne Conklin at DSN 471-7452 or Commercial (210) 221-7452; email: Lynne.Conklin@email.cs.amedd.army.mil): Interactive training program for treatment of basic tasks; e.g., chest wound. It contains hardware such as components such as soldier mounted, voice-operated computer, with a heads-up, helmet mounted display.

- MENTIS (POC: Ms. Lynne Conklin at DSN 471-7452 or Commercial (210) 221-7452; email: Lynne.Conklin@email.cs.amedd.army.mil): Multimedia Wearable Computer.

- MEDIC (Medical Interactive Courseware) (POC: Ms. Lynne Conklin at DSN 471-7452 or Commercial (210) 221-7452; email: Lynne.Conklin@email.cs.amedd.army.mil): MEDIC is the cornerstone for the development of multimedia lessons from the Medical Specialist MOS 91B training program for delivery via distance learning.

- Development of the Knowledge Management Network (KMN Website) (POC: Mr. Greg McGee, Chief Knowledge Officer at (210) 221-8530; email: gmcgee01@mnsinc.com): Its development began in May 1997 under the Chief, Leadership and Instructional Innovations Branch (LIIB) at the Center for Healthcare Education and Studies (CHES), AMEDDC&S. Its mission is to help meet the information explosion challenge of the 21st century.

- MediaMed Interactive Program (http://www.creativesciences.com): Developed by Creative Sciences, Inc., is used for training military nurses and medics.

- The Life Support for Trauma and Transport (LSTAT) Medical Equipment from Northrop Grumman (Northrop Grumman Corporation, Advanced Systems & Technology, Phone (562) 948-9627 Fax (562) 942-5147): It is a compact, transportable, individualized medical care unit. The LSTAT provides a means for projecting sophisticated trauma care forward onwards the site of injury.

- A Defibrillator from Survivalink (http://www.survivalink.com).

- Virtual Laparoscopic Interface/Laparoscopic Impulse Engine developed by Immersion Corporation (http://www.immerse.com/WWWpages/medical.html): Both hardware products were designed for virtual reality simulations of Laparoscopic and Endoscopic surgical procedures. They were not considered because their use is more related to virtual reality simulation.

- Limb Trauma Simulator developed by MusculoGraphics, Inc. (http://www.musculographics.com/lts.htm) It is a surgery simulation system for trauma management. It applies to limbs only.

- ACLS Patient Simulator developed by Medical Simulation Software (http://ourworld.compuserve.com/homepages/medsimsoftw/): This site doesn't exist anymore.

- ERCode! developed by HealthGuild Software (http://www.healthguide.com/ercode/): It simulates a person suffering from a cardiac or respiratory crisis in the emergency room. However, this software only supports cardiac and respiratory emergencies.

- GasMan developed by GasMan Software (http://www.gasemanweb.com/1.html): GasMan is a software for teaching and simulating anesthesia uptake and distribution. It graphically simulates the pharmacokinetics of anesthesia administration. However, this software only deals with anesthesia.

- Trauma One! developed by Mad Scientist Software (http://www.netmedicine.com/open/benefits/madsci/trauma/index.htm): This software simulates multiple-trauma patient. It allows physicians and surgeons to learn trauma management during initial care of multiple-trauma patient.

- Full Body Adult Rescue/CPR Manikin developed by Simulaids, Inc. (http://simulaids.com/catalog/full-body.htm): This mannequin is used for demonstrating and training proper CPR techniques. It simulates the resiliency and weight of a human body for realistic practice in transport rescue and lifesaving medical procedures. This was not considered because it does not possess simulation capabilities and is used only for CPR operations.

- MEDIC-1 developed by Emergency Operations, Inc. (http://www.emergencyops.com/): It is a multiple casualty disaster triage training simulation, and part of an innovation project of the Canadian Coast Guard to provide computer-based instruction to its Rescue Specialists. It provides the experiences for the range of decisions associated with triage that medical personnel would face in the field with multiple casualty disaster incidents. It allows personnel to practice on first stage triage (patient assessment) and second stage triage (evacuation) in a time-constrained environment. The software is trauma management simulator and was not considered.

- IEMS[3] developed by Data Communications Corporation (http://www.datasim.com/): This is a simulation system used for addressing strategic planning and tactical issues of the emergency medical services.

- CathSim Intravenous Training System developed by HT Medical Products (http://www.ht.com/): This system is designed to improve training in intravenous therapy. The product was not considered because of its restricted use as a catheter insertion training device.

- Evita 4 developed by Drager Medical Australasia (http://www.draeger.com.au/products/adultcare/evita4/index.shtml): This product is a ventilator.

- Anesthetic Gas Machine Modulus SE developed by Ohmeda (http://www.boc.com/ohmeda/company/product/prodinfo/delivery/modse.htm): This hardware is an anesthesia delivery system. It provides anesthesia delivery and monitoring flexibility. The module offers the selection of three vaporizers and four gases.

- Patient Monitor developed by Hewlett-Packard (http://www.dmo.hp.com/mpg-pr/worldcup_prod.html): This is a portable lightweight patient monitor. It provides four simultaneous parameter measurements such as cardiac function, respiration, temperature and SpO2.