A Report of an Integrated Research Team Meeting on Military Medical Simulation Training

On 16-18 February 2000, the Telemedicine and Advanced Technology Research Center (TATRC) convened an Integrated Research Team (IRT) meeting for Medical Modeling and Simulation (MM&S), co-hosted by the U.S. Army Medical Research and Materiel Command (USAMRMC) and the U.S. Army Simulation, Training and Instrumentation Command (USASTRICOM). Given the complexity of the issues, TATRC chose to use the IRT process as a forum to build a series of technology road maps in this ever-burgeoning field. The conference outline was designed to enable materiel developers, combat developers and other government agencies to present their concepts about how modeling and simulation could – and should – be developed to meet military needs. From the outset, the participants recognized that MM&S would have a much wider application than the original intent to develop a training tool for medical readiness. It is inevitable that MM&S will provide a basis for training and education across the entire spectrum of future health care.

The program began with a vision statement from the Commanding General of MRMC, who outlined current deficiencies in military medical readiness training: an inability to train in peace for the needs of war; unique elements of combat medicine; the size of the force to be trained; and the eclectic nature of the force. Following the General’s introductory comments, several speakers expanded the discussion of training inhibitors and recognized that the current use of animals to provide training was problematic and may be severely curtailed in the future. They contended that the efforts of the clinical community to provide alternative training in civilian trauma centers and pre-hospital EMS systems across the nation would prove inadequate to meet the demands of military medical readiness.

Representatives from government, academia and industry expressed the need for simulation training from their own vantage point. Military and federal agencies currently using Commercial Off-the-Shelf (COTS) simulators in medical readiness training gave their views of the value of simulation in training and their future needs. TATRC-funded investigators provided details of their ongoing research and highlighted emerging and inchoate science. In addition, a number of researchers not funded by TATRC but identified as on the leading edge of simulation modeling science were invited to present the latest work in their respective domains.

The conference culminated in an engagement of key stakeholders in the contemporary MM&S world who converted enlightened self-interests into agreement on conclusions and recommendations to the Commanding General, MRMC, as a basis for the development of a MM&S technology road map.
The Government Perspective

Government representatives universally acknowledged the urgent need for simulation to fill the current training gap, reduce the reliance on animals and compensate for the diminishing numbers of patient encounters experienced by contemporary physicians and other healthcare providers in training. Although several governmental agencies expressed interest in medical simulation training, few currently enjoy this tool. The most notable exception is the Veterans Health Administration (VHA). The National Aeronautics and Space Administration (NASA) that pioneered the use of simulator trainers has no medical training simulator in its inventory.

The Oak Ridge National Laboratory (ORNL) has specific but nascent interest in complex human modeling to combine both accurate anatomical structure and physiological function. Though challenging, this modeling project has the potential to greatly enhance understanding of the human body and its response to insult and injury.

Figure 1: Oak Ridge National Laboratory vision of a Virtual Human
(Courtesy of Clay Easterly, PhD, Oak Ridge National Laboratory)

The National Institute of Health (NIH) recognizes the Visible Human project as a foundation for building functional models from image data but notes the requirement for both more data, and increased fidelity. The Veterans Health Administration (VHA) entered a current year budget item for the establishment of a production training simulation center. The VHA made clear its intent to invest in simulation training, possibly performance assessment, and the use of simulation for the understanding of errors and successes across the spectrum of their healthcare services. Given the interaction of missions and the growing links between VHA and DOD, there is eminent good sense in adopting a joint DOD/VHA strategy on MM&S. This might well enable DOD to concentrate on the development of simulation for practical skills training and the VHA to develop simulation protocols for behavioral education and error mitigation.
The US military has taken the first deliberate steps to launch simulation as the core of future combat medical training. A Joint Trauma Training Center has been established at the Ben Taub Hospital, Houston Texas. The Center capitalizes on the extensive experience of the hospital staff and the high levels of trauma typical in a major city and its environs to train military field surgical teams prior to operational deployment. To meet this aim, the training staff uses a combination of simulator training and “hands-on” real trauma cases. A nascent simulation center is being developed on site, using a range of simulators from existing Commercial Off The Shelf (COTS) technology.

Concurrently, the National Capital Area Medical Simulation Center has been established under the aegis of the Uniformed Services University of Health Sciences (USUHS) at the Forest Glen Annex of the Walter Reed Army Medical Center. A number of other simulation centers are being developed, most notably at the Army Medical Department (AMEDD) Center and School, San Antonio, Texas and the Special Operations Medical Academy in Fort Bragg, North Carolina. One of the first medical simulation centers, developed by the Army National Guard at Fort Indiantown Gap Pennsylvania, has made great inroads in training using a digitally enhanced mannequin simulator.

**The End User Perspective**

Representatives of agencies responsible for training military trauma care providers presented their needs for enhanced training tools. End user agencies included the AMEDD Center and School, the Defense Medical Readiness Training Institute (DMRTI), USUHS, the Special Operations Forces medical community, Ranger medics and medical trainers from the reserve components.

Each reported its experience with simulator trainers, evaluated their effectiveness, detailed their perceived advantages and disadvantages, and identified the need for specific improvements. Overall, the end users commonly agreed that simulator trainers are a vital and urgently needed tool. The aim should be to use simulators in place of animals for basic skills training and to use simulators to teach and hone other skills that are currently gained by practice on human patients. The end-user community also
recognized that the current range of COTS simulators needs rigorous performance assessment, both to identify the skills and procedures most benefited by simulation and to provide a requirements basis for further research and development. The user community stated clearly that while they recognized the need for investment into the development of futuristic simulation envisaged as Total Immersion Virtual Reality (TIVR), they also needed enhanced versions of the current COTS range to meet today’s needs. The consensus was a twin-track approach involving the purchase of current simulators and incremental enhancements to them while at the same time identifying and investing in the long-term strategy for TIVR. The key criteria for the current COTS technology were and would remain cost, ruggedness and logistic support. The user community made an urgent case for expanding the role of simulators to improve initial and sustainment training of far-forward care providers. The trainers of these combat medics felt that simulation training was needed to support the intense and time-critical demanding learning of combat trauma skills.

Figure 4: Special Operations Forces (SOF) medics routinely treat patients worldwide in austere conditions. (Courtesy US Army Special Operations Command)

The trainers assessed current versions of computer-based training programs as needing more accurate portrayal of medical conditions, outcome-oriented feedback from

Figure 5: Venous catheter procedure under battlefield conditions (Courtesy US Army Special Operations Command)
intervention measures, and greater realism in scenarios. Similarly, improvements were recommended for digitized mannequins, including better assessment tools, such as pulse differentiation, skin color changes, temperature differentiation and representations of bodily fluids.

End users tended to regard virtual-reality type training simulators as being more relevant to trauma care at areas behind the combat zone. There was consensus that the IRT should recommend continued research on virtual-reality type training simulators, but there was general acknowledgement that much work had yet to be done in the development of enabling technologies.

Categories of Simulation Training
Four broad areas of medical simulation emerged from discussions:

Area 1 – PC-Based Interactive Systems. There are many of these systems already on the market and in wide use in military medical training. They have much merit, particularly in learning and rehearsing processes in clinical care. The costs of this technology make it ideal for individual use. The major limitation it currently faces is the lack of quality assurance, particularly in the verification of clinical curriculums and program protocols.

Figure 11: Simulation Technologies for Advanced Trauma Care (STATCare) Trauma Patient Simulator (TPS), under development for TATRC (Courtesy of Paul Kizakevich, Research Triangle Institute)
Area 2 – Digitally Enhanced Mannequins. This concept utilizes the medical mannequins that have been in use as medical trainers for many years, particularly for teaching airway management. The mannequins are enhanced by the use of sophisticated materials and more detailed anatomical structures. The solid structures are connected to PC-based systems, enabling the mannequins to demonstrate signs and symptoms of injury and to react to clinical intervention. These systems are relatively expensive but may very well become less so with further development and manufacture. Their cost limits their standalone capability, but they have much utility in team training. As yet, their major function is in teaching airway and circulatory system management but efforts are underway to broaden their capability, particularly to integrate into wider systems for team task training.

Area 3 – Virtual Workbenches. The first steps in utilizing virtual reality for medical skills training have taken the form of so-called virtual workbenches. The technology and sophistication is growing rapidly. At one end of the scale are relatively simple, inexpensive but highly effective PC based systems that enable the teaching and practice of an array of clinical and diagnostic procedures such as catheterization and bronchoscopy. At the other end, there are complicated and expensive simulators that enable the user to practice complex laparoscopic surgery. The state of the art makes them ideal for practicing minimally invasive procedures, but the limitations in haptic feedback restrict their utility. Cost is dependent upon complexity.
Figure 14: HT Medical Systems’ Bronchoscopy Simulator, a medical simulator platform for realistic, procedure-based content for cognitive and motor skills training.
(Courtesy of Greg Merril, HT Medical Inc)

Area 4 – Total Immersion Virtual Reality. The technological challenges to developing Total Immersion Virtual Reality are many and varied. However, without advances in true virtual reality it will not be possible to meet the demands of training for combat casualty care and other forms of clinical training will be severely limited. Among the challenges to overcome is complete haptic feedback that enables a user to “feel” a wound and for tissue to react to touch. The development of a virtual physiology to match the existing anatomy is also a great scientific test. Work is underway in all these areas but success will be contingent upon the level of investment in the future.

Figure 15: Under development by the Center for Integration of Medicine and Innovative Technology (CIMIT), a Boston-based consortium, the Tissue Material Property Sampling Tool (TEMPEST) is a laparoscopic-compatible biomechanical tissue modeling tool for in-vivo measures of small scale organ deformation in animals.
(Courtesy of Steve Dawson, MD, Massachusetts General Hospital)
Each area had relative value in either availability or cost, and each required research investment to attain effectiveness. Deliberations produced the framework of a broad-based investment strategy - both near and far term - for MM&S research support. Similar discussion highlighted the need for a single entity to integrate the many and diverse research efforts related to MM&S.

**Medical Simulation Technology Currently Funded by DOD**
The TATRC portfolio of medical simulation is made up of a number of interrelated research efforts that fall into the four broad categories of simulation.

**Category 1 – PC-based Decision Teaching Tools.** The Simulation Technologies for Advanced Trauma Care (STATCare) project, conducted by Research Triangle Institute, Research Triangle Park, North Carolina, is a PC-based, interactive CD-ROM simulator system. The program focuses on skills required to assess multi-trauma incidents, to provide command and control and initial first aid. The objective is to practice rapid assessment decision-making skills. The system includes a variety of scenarios and a spectrum of the most commonly encountered trauma conditions. Each scenario requires response to both the overall scene and the physiological condition of the individual patients.

**Category 2 – Digitally Enhanced Mannequins.** The Combat Trauma Patient Simulator (CTPS) project, conducted by Medical Education Technologies Inc, Sarasota, Florida, consists of digitally enhanced mannequins that demonstrate signs and symptoms of injury and that react to clinical intervention.

**Category 3 – Virtual Workbench Technology.** The virtual workbench simulation technology is exemplified by the range of COTS simulators produced by HT Medical Systems Inc., Rockville, Maryland. They provide a high level of realism for training and practice of a number of minimally invasive procedures. The latest simulator, the virtual ureteroscope, was funded by TATRC.
Category 4 – Total Immersion Virtual Reality. The Center for Integration of Medicine and Innovative Technology (CIMIT) Boston, Massachusetts, has begun a series of research projects designed to provide the enabling technologies for Total Immersion Virtual Reality (TIVR).

“Next Generation” Research and Development for Medical Simulation
The eventual aim is to produce an environment that totally immerses the individual or group of individuals in the combat scenario and the medical problem. Only in this way can a truly realistic approximation of medical and military medical challenges on the battlefield be achieved. The development of realistic haptic feedback to the hand is vital to achieving this breakthrough.
Dimensional Media Associates Inc., New York, New York, is developing technology that provides a true 3D floating volumetric image. The image is produced in a volumetric format, enabling the projection of images in a form that gives realistic depth of field and three-dimensional images (3D). The system will also provide a two-handed tactile interface for direct interaction with a 3D image using Sensable Technology’s PHANTOM haptics device. The idea is to create a floating 3D image out in front of the display. Stereoscopic glasses will not be required and the viewer can reach out and account for the energy exactly where it appears to be. The software will determine how that image reacts. The ultimate goal is to create a collaborative multi-user workstation. Multiple systems will be connected through a LAN to establish a joint environment for which several users will see the exact information. Users will be able to work as one team modifying the same information that other users can see. The aim will be to simulate multiple key members in a surgical scenario working together, each with their own perspective.

![Conceptual diagram of Dimensional Media Associates’ surgical simulation workstation showing floating 3D image & co-aligned force feedback interface. (Courtesy Alan Sullivan, PhD, Dimensional Media Associates)](image)

**Figure 7:** Conceptual diagram of Dimensional Media Associates’ surgical simulation workstation showing floating 3D image & co-aligned force feedback interface. (Courtesy Alan Sullivan, PhD, Dimensional Media Associates)
A research team at the University of Michigan is developing a model for individual and team training in the area of medical and surgical training. The concept is to use a mannequin-style “human patient simulator” in an artificial environment known as a Computer Autonomous Virtual Environment (CAVE). This uses COTS technology to project an operating room or other medical setting within an existing building. This technology was originally designed to display the concept of a mobile OR contained in a specialized vehicle and designed to provide care to rural areas or disasters. Though not totally virtual reality, it has merit in using COTS to amplify the environmental stimuli. It might best be described as a digitally enhanced or enriched environment.

Figure 8: The University of Michigan’s CAVE (Computer Autonomous Virtual Environment) (Courtesy of Dag von Lubitz, MD, University of Michigan)

The University of Houston is using its experience in simulation research related to the space program, to develop a test bed for so-called “checkpoint” scenarios. This enables individual or team training in enriched environments that provide “challenges to the training experience”.
Southern Methodist University is engaged in research of master-slave robotic manipulators. Using pneumatics, they developed a robotic shoulder and elbow that are kinematically similar. The master is responsible for providing resistance, in the form of joint torques to the motion of the operator in order to reflect the external interactions of the slave manipulator. Thus, pressure feedback replaces haptics. This research seeks to develop a haptics interface that immerses both arms of an operator into the virtual world.

Figure 9: Conceptual image of Suspended Exoskeletal Pneumatic Haptic Interface (Courtesy of Yildirim Hurmuzlu, PhD, Southern Methodist University)

Ethereal Technologies, Ann Arbor, Michigan, is utilizing an image rendering system to develop a work station that displays in real time, in front of the observer, the ethereal model that the computer generated, which is in full color and which also has acoustic and haptics interface.

Figure 10: Image produced by Ethereal Technologies’ flexible membrane mirror (courtesy of Bob Andrews, Ethereal Technologies)

Virtual Presence LTD, Lynnfield, Massachusetts, is combining mathematical modeling and interactive computing to produce better minimally invasive therapies.
Conclusions and Recommendations

Setting aside personal and commercial self-interests, the conference participants reached conclusions that underpinned a strategic road map for supporting research related to medical modeling and simulation. They agreed that simulation training is a viable solution to problems of readiness training, that each of four distinct categories of simulation trainers have unique immediacy and cost factors, that products in each category of simulator trainer require specific enhancements, and that user needs should drive medical simulator product development. To support these conclusions, the conference participants recommended the following actions:

1. Establish a working group to identify user needs and translate them into clear mission requirements. The AMEDD Center and School is the logical agency to lead this working group.
2. Establish a working group to match needs and training resources with the Technology Readiness Levels (TRL) of the developing MM&S technologies. STRICOM would logically lead this working group.
3. Establish a working group to develop a team building and funding consortium to leverage technologies and resources across a broad spectrum of industry, academic and government partners. TATRC is the logical agency to lead this working group.
4. Establish Integrated Product Teams (IPT) to provide guidance for the management of projects with specific individual products.
5. Develop a methodology and model to identify clear gaps in current training and the specific needs for simulation.
6. Provide regular reports of working group and IPT activities and an overall report to the Director of TATRC.
7. Identify an agency to integrate the many and diverse research efforts related to MM&S.

Figure 16: IRT Steering Group – Standing, left to right – LTC Albano, CPT Herold, Ms Pettitt, CPT Fasano, Dr. Moses, COL Gerber, Mr. Clyburn, Mr. Leitch, COL Vandre, Mr. Magee, COL Johnson. Seated, left to right – Mr. Wiehagen, LTC Bauer
After reviewing the conclusions of the IRT meeting, the Commanding General of USAMRMC approved the further development of a fully integrated, tech-based investment strategy for MM&S, in direct support of the Joint Warfighter Science & Technology Plan. He also approved follow-on IRT meetings to structure appropriate IPTs and devise best methods of leveraging consortium involvement, and he designated the Telemedicine and Advanced Technology Research Center (TATRC) as the Command oversight agency for the management of MM&S research.

**Progress Report of Post-IRT-Conference Actions**

The overall strategy for support of research related to medical simulation training encompasses both short-term support for enhancement of current and evolving simulators; such as CD ROM and mannequin types, and long-term investment in virtual workbench and virtual reality type simulators. Project managers followed specific IRT suggestions to improve realism and clinical appropriateness of CD ROM simulators, and collaborated with European scientists to add such features as smell to training scenarios. Product developers seek to improve skin texture and response to interventions for the digitized mannequin simulator. In addition, the Army Center for Total Access is conducting a rigorous independent test and evaluation of the METI CTPS system.

The AMEDD Center and School hosted a user-needs meeting related to medical simulation training and established a working group to identify user needs and translate these needs into official military mission requirements. The Directorate of Combat Developments at the School is now preparing appropriate documents to establish valid military requirements for medical simulation training.

An Integrated Product Team (IPT) has been established for the Combat Trauma Patient Simulation system. As the designated steering group, the IPT provides overall programmatic guidance and specific recommendations for product enhancement, user requirements, testing and evaluation and deployment. The IPT meets quarterly to maintain a vigorous product refinement effort.

TATRC has contracted the services of expert consultants to assist in integration of the overall strategy for medical simulation training research. Doctor Howard Champion will provide expert advice on trauma care, tissue modeling and medical applications of simulation training. Doctor Gerald Higgins will ensure that performance metrics are applied to all aspects of technological developments related to medical simulators.

TATRC has undertaken a vigorous search to identify sources of funding to support medical simulation research. Close cooperation with STRICOM and a partnering effort with the Army Combat Casualty Care Research Directorate have yielded more than $2 million for the funding of two Science and Technology Objective (STO) projects. Successful competitions in the Small Business and Innovative Research (SBIR) program and the anticipation of success in the Small Business Technology Transfer (STTR) program will bring funding support for two Phase I projects with the potential for significant dollar growth in Phase II research. Currently, proposals seeking more than $7 million are awaiting funding decisions by several agencies.
The TATRC staff have presented the general outline and findings of the IRT meeting to military, medical and other professional conferences in the United States and Europe, in order to develop collaborations between agencies and build relationships among scientists developers, manufacturers and users. Included among these conferences were the Association of Military Surgeons of the United States (AMSUS), the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), Medicine Meets Virtual Reality (MMVR), the International Training and Education Conference (ITEC), the Special Operations Medical Association (SOMA), the International Society for Optical Engineering (SPIE), and the Advanced Technology Applications to Combat Casualty Care (ATACCC).

Several investigators whose projects are managed by TATRC have successfully developed prototype devices of medical simulators. These prototypes are available for demonstration at TATRC and include the STATCare simulator, the ureteroscopic endoscopic simulator from HT Medical Inc., and an advanced version of the METI human patient simulator mannequin.

Several collaborations have developed among the participants of the IRT meeting. CIMIT and Ben Taub Hospital are cooperating on tissue modeling, Georgetown and Johns Hopkins Universities are cooperating on robotics and spine surgery simulation, and Research Triangle Institute and Special Operations Forces medics are cooperating to develop scenarios for medical training. The establishment of formal and informal cooperation between USASTRICOM and USAMRMC has had a profound impact on post-IRT progress and bodes well for continued success in this vital military medical readiness initiative.

For further information about this meeting or TATRC’s Medical Modeling and Simulation program, please contact Mr. J. Harvey Magee, Projects Officer, Medical Modeling and Simulation, 301-619-4002, magee@tatrc.org, or Dr. Gerry Moses, Projects Supervisor, 301-619-4000, moses@tatrc.org.