

How Modeling and Simulation Can Support MEDEVAC Training

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Abstract

Airborne medical evacuation (MEDEVAC) is vital for maintaining a safe lifeline for military personnel in tactical operations. Medical evacuation must be reliable and efficient, independent of the threat level of the operation. Not only must the medical personnel be proficient in trauma surgery, they also must be able to work as a team in the confined environment of a helicopter. The various stages of MEDEVAC training reviewed in this paper, from individual skill training to full-scale, applied tactical training, lend themselves to a variety of simulation tools and devices. Promising modeling and simulation methods and tools for training individuals, teams, and taskforces are identified. Finally, we discuss how present and future means of modeling and simulation can support and enable MEDEVAC training to meet today's changing and challenging missions.

Introduction

Modeling and Simulation have been used to provide and enhance training in many areas. New missions and new operational needs are setting focus on the increased use of helicopters in both traditional and new settings. The cost savings of using simulation tools and devices rather than actual resources have been documented many times in the past. Training accomplished using actual aircraft costs over \$3000 an hour while realistic simulation packages can provide that same training environment for a fraction of the cost. The capabilities of the simulations can meet the training need for increased physical skills, enhanced decision-making situations, crew coordination activities that save lives and reduce human error in actual situations.

No simulation impact has been more dramatic than the advances seen in the medical field and in particular, the training being realized by the medical evacuation (MEDEVAC) community. The evolution of MEDEVAC mission time from a traditional 30 minutes in the past to 3 to 4 hours now, and the increase in mission and skill requirements placed on the medics, requires much more sophistication in the training provided. Such complex missions include Special Forces Operations, Forward Surgical Team Support, Combat Search And Rescue,

National Disaster and Humanitarian Relief, in addition to battlefield casualty evacuation.

MEDEVAC is vital for maintaining a reliable lifeline for military personnel in tactical operations. Medical evacuation must be reliable and efficient independent of the threat level of the operation. The outcome of a MEDEVAC mission depends to a large extent on the responding individuals' and units' ability to cooperate and the overall coordination of their efforts. The MEDEVAC team must work together with other units and communicate through the same command and control system as other cooperating units in order to act efficiently and safely.

Despite the uncontradicted importance of medical evacuation the training of these skills are often overlooked (Brant, 2002; Miller, 2002). One reason for this is that we want to use as much of the training time as possible for the main combat skill, forgetting the realities of the real battlefield. Another reason is the complexity of a MEDEVAC mission and the problem for the trainer to provide a pedagogical and realistic training situation for different categories of trainees. Thirdly, commanders are reluctant to pull soldiers out of valuable field training time to evacuate them from a maneuver unit through the medical system.

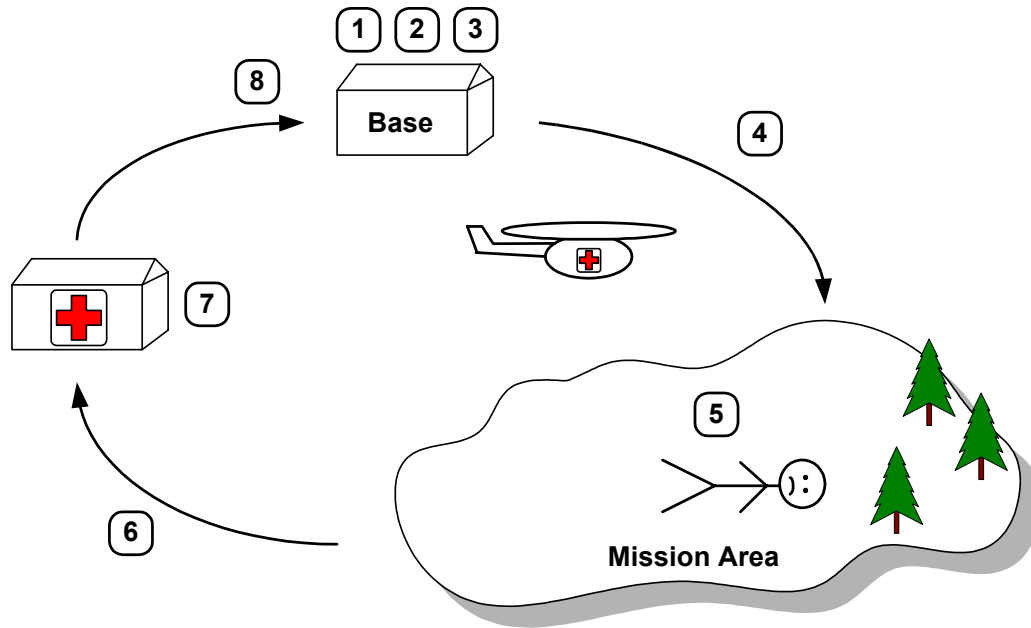


Figure 1: A schematic overview of a MEDEVAC mission. The numbered boxes denote the eight different phases of a MEDEVAC mission: 1) Preparation, 2) Request for MEDEVAC, 3) Dispatch, 4) Insertion flight, 5) On scene stabilization, 6) In-flight care, 7) Transfer of patients to higher care, 8) Recovery and mission documentation. Each phase is described in more detail below.

Efficient training is fundamental to acquire and maintain the types of individual, team and management skills that are required to respond adequately during a MEDEVAC mission. Helicopter crews will face new training challenges in the preparation for new tasks. Pilots will still need traditional flight training, but they will also need training opportunities with their medic teammates to create an efficient MEDEVAC unit. In addition, they will need increased skills in battle space coordination. Finally the command and control staff that communicates with the units in the field must have a thorough understanding of the realities of a MEDEVAC mission. They must receive training to support the field units without increasing the workload of the MEDEVAC units' personnel.

Several methods and tools have been presented for supporting the training of medical personnel involved in military and civilian rescue operations. Typically, these state-of-the-art training aids address a specific training issue concerning a particular function in an operational scenario. To support multiple stages of MEDEVAC training several training methods and training systems have been put forward. However, there is no single method or system that encompasses all these training areas. Hence, there is a great need for methods to help training managers identify training requirements and training opportunities, to select appropriate training aids, and to devise effective training programs (see for example van der Hulst (1997),

van Berlo & van Rooij (1997), Barron & Evans (1997) and Bowden & Cook (1999).

In this paper we present how methods and tools based on modeling and simulation can support multiple stages of MEDEVAC training. We describe the various stages ranging from individual skill training to full-scale applied tactical training of MEDEVAC units. We emphasize the importance of training documentation, analysis and feedback during all these stages of training. Finally, we discuss present and future training needs and opportunities relevant for the MEDEVAC community.

In the next section we briefly describe a MEDEVAC mission. Then we devote two sections to an analysis of training needs and an inventory of training opportunities in MEDEVAC missions. Finally, we discuss trends and future developments of simulation-based training tools for MEDEVAC training and state our conclusions.

MEDEVAC Missions

MEDEVAC missions include several parallel activities at three main locations (Litteral, 2002). The first is *the MEDEVAC base* where the units and the command and control function are deployed. The second main location is *the Mission Area* around the point of injury where the patients are located. The mission area characteristics depend on the type of operation (see Table 1). They vary

from single unit deployment in low-threat environments to joint operations with multiple units in combat. For example, in a peacetime mission a single autonomous MEDEVAC team may take the fastest route to bring a single casualty to the closest hospital. On the other hand, in a joint warfare operation multiple MEDEVAC units must operate in a coordinated manner to recover large number of casualties in a hostile environment. The command and control of the mission becomes increasingly important when the number of teams grows and the threat levels become higher. In particular, joint operations necessitate thorough unit coordination and in-flight collaboration with multiple units and commanders, both in the air and on the ground, in order to protect the MEDEVAC unit in a hostile environment. The third main location is *the facility of higher care*, which can be an ordinary hospital or a field hospital. The personnel receiving casualties at the hospital need pre-arrival information on the patients. Moreover, on some occasions a medical doctor can support the flight medic from a remote location to provide better ‘care in the air’.

Regardless of the type of operation, MEDEVAC teams execute *MEDEVAC missions*. Each mission can be divided into eight separate phases according to Figure 1. The eight phases of a MEDEVAC mission are (Litteral, 2002):

1. *Preparation*. Equipment is checked and the team is standing by for MEDEVAC alert. The level of readiness may vary from standing by at the base, to flying alert runs at the outskirts of a battlefield.
2. *Request for MEDEVAC*. The team gets information related to point of injury or the fixed facility, and also the number and types of casualties.
3. *Dispatch*. The aircrew check maps and prepare the insertion flight while the other members coordinate special equipment.
4. *Insertion flight*. During the insertion flight the team members perform their crewmember duties, such as navigation or looking out for threats. Depending on the type of mission and the threat level, the command and control function at the base coordinates the MEDEVAC unit, its close air protection, and the requesting unit on the ground. The flight medics review the injury report accompanying the MEDEVAC request and prepare for the treatment of the patient.
5. *On scene stabilization*. The extent of the on scene stabilization care is adapted to the threat level. In peacetime or in operations other than war extensive work may be performed. Otherwise, effort is made to extract the casualty as quickly as possible.
6. *In-flight care*. During the extraction flight to the specified care facility, the aircrew operates the platform. The flight medic gives the patient the

appropriate in-flight care and communicates, if required, with a medical doctor.

7. *Transfer of patients to higher care*. Arriving at the care facility, the flight medics hand over each patient and their case records to the receiving personnel.
8. *Recovery and mission documentation*. Returning to base all equipment is restored and the mission is documented with flight logbook and patient charts.

These phases are always present in a MEDEVAC mission but the activities in each phase can be different depending on the type of operation (see Table 2).

The success of a MEDEVAC mission is determined by three critical factors:

- The total time elapsed from the injury to the time when the patient receives higher medical care.
- The transportation environment, which should be as gentle as possible, in order not to aggravate the medical status of the patient.
- The treatment over time given to the patient.

Balancing these interdependent factors with respect to the type of operation and the specific conditions at hand is a primary challenge in MEDEVAC missions.

Training Needs

Training needs can be identified at several organizational levels ranging from the individual level to the operational level. In the light of the limited resources for training it is important to identify the different stages of MEDEVAC training and apply the methods and tools that are most likely to be effective for that stage with respect to the desired outcome. (Bowden & Cook, 1999).

Key MEDEVAC personnel include flight medics, pilots, navigators and remotely located staff personnel. All personnel require a certain amount of individual training. This training is essentially aimed at the skills required to perform MEDEVAC missions and at providing basic training in personal protection. All MEDEVAC categories of personnel require selected additional training to perform specific tasks. For example, the flight medics need training in field triage, first aid, and patient stabilization. Commanders, leaders and staff personnel require tactical training to handle flight missions and to coordinate MEDEVAC units with the armed units for their protection. The pilots and navigators need flight training in different environments and under different threat levels, ranging from peacetime transportation to combat MEDEVAC.

Team training (Dyer, 1984; Salas et al., 1992) is required for the MEDEVAC teams. They must learn how to work within and around the helicopter and how to operate special medical equipment.

Table 1: MEDEVAC missions in different types of operations.

Type of operation	Threat	Type of injuries	Environment
Combat	Military opponent	Battle injuries	Battle field
Peace enforcement	Military opponent / hostile environment	Battle injuries, mine incidents	Conflict zone
Peace keeping	Hostile environment, criminal factions	Battle injuries, mine incidents, civilian injuries	Conflict zone
Humanitarian relief	Riots, criminal factions, environmental threats, sanitary threats	Dehydration, diseases, fatigue	No mans' land, refugee camps
Disaster relief	Rubble, power cables, gas leaks, environmental threats, sanitary threats	Bruises, contusions, injuries caused by crushing or squeezing	Disaster area

Table 2: Vital functions in different types of operations.

Type of operation	Medical treatment	Command and Control	Force protection	Aviation
Combat	Trauma care	Military command and control	Secure landing zone, armed escort, safe route	All weather, all terrain, tactical flight
Peace enforcement	Trauma care	Multi national	Secure landing zone, safe route, roles of engagement applied to Peace enforcement	All weather, all terrain, tactics applied to roles of engagement
Peace keeping	Trauma care	Multi national	Secure landing zone, safe route, roles of engagement applied to Peace keeping	All weather, all terrain, tactics applied to roles of engagement
Humanitarian relief	Care for dehydration, diseases, fatigue	Multi national, multi organizational	Unit self defence, safe landing zones, sanitary protection	Civilian requirements
Disaster relief	First aid, stabilization	Multi organizational	Safe landing zones, personal protection, sanitary protection	Civilian requirements

Command post training is a special form of team training for command-and-control personnel. They must learn how to manage a complex situation under stressful circumstances often without complete information about the situation in the field.

Taskforce training (Jenvald, 1999) enables all personnel to engage in a common exercise, where skills can be applied in a realistic scenario. This type of training is essential as it can produce learning situations that usually do not occur in individual training or team training. Particularly, with real people in the field, the command-and-control functions will encounter a multitude of foreseen and unforeseen situations. This variety is hard to reproduce in scripted command-post training. Furthermore, the teams in the field may experience friction due to various practical problems and the need to cooperate with other teams. Combat Search and Rescue (CSAR) is an example of a task suitable for taskforce training.

Preparing for different types of operations

Medical evacuation must be reliable and efficient independent of the type of operation. The survivability heavily depends on if first aid is given to the patient at the accident scene before the MEDEVAC team arrives. In addition, there are three main critical factors for a MEDEVAC mission. The first factor is the total time from that the incident occurs to the time when the patient receives higher medical care. The second factor is the

transportation environment, which should be as gentle as possible, in order not to aggravate the medical status of the patient. The third factor is the treatment over time given to the patient.

Depending on the type of operation, in which the MEDEVAC mission takes place, these factors will be affected differently. In a combat operation more time is needed for coordination with friendly air and ground units.

The need to avoid enemy contact – for example, by flying in controlled air space and low terrain – will increase transportation times, and make treatment more difficult in flight. Table 1 shows how the type of operation affects what type of injuries the MEDEVAC team is likely to encounter.

Arguably, if a MEDEVAC team can manage their job during a combat operation, they can manage all other operations with a lower level of threat. However, an operation such as humanitarian relief is often multinational and multi-organizational, which leads to new requirements on cooperation and communication. Also, the threats and the corresponding need for force protection are different. In a combat operation the military opponent is the main threat, whereas in a disaster relief operation the main threat are diseases and sanitary problems.

Although combat is the most complex operation, the other types of operations will add different types of complexity and require new means of training.

Training Opportunities

The goal of training is to enable personnel to respond appropriately to a wide range of situations. Trainers must state objectives clearly and design instructions accordingly to guide the learner, and provide a framework for evaluation. Moreover, the trainers must define key tasks and establish performance measurement criteria for evaluation. Initial conditions and resources must be identified, and a timeline of events must be prepared. A direct result of this preparation phase should be the development of a realistic scenario that will meet the training needs of the participants.

A scenario sets the stage for the training situation, provides the initial and boundary conditions of the starting situation, and may also portray a chain of events typical for the situation. A good training scenario includes; (1) an active response from participants, (2) a challenge for the participants, (3) realistic conditions, (4) an appropriate or best way to respond to the situation, and (5) a link from response to outcome.

In the following sections we explore the training opportunities in the modeling and simulation area for each MEDEVAC crew category. Our starting point is the main critical factors for a MEDEVAC mission. The final aspect is the fact that despite the importance of the MEDEVAC capability for all field units, most training commanders are unwilling to let their personnel become victims in the MEDEVAC training chain, taking them away from training in their main combat skills (Brant, 2002).

Aircrew

The pilot and navigator need all-weather and all-terrain flight training. They need training in order to decrease the time for flight preparation and coordination with other field units. They also need to be able to safely load the patients into the helicopter either by landing or by hovering over the landing zone. Finally, they need to manage as smooth flight as possible in order to make it possible for the flight medic to treat the patients and to minimize the strain on the patients due to the flight. Gaming and command-post training systems supports training of flight preparation and coordination. Traditional flight simulators supports training in navigation and pilot skills under different conditions, and live training monitoring systems provide full-scale live training with simulation, documentation and debriefing support.

Flight Medics

The flight medics need training in triage, advanced first aid, patient stabilization and in flight care. To increase the possibility for the medics to train together with different field units, mannequins and advanced patient simulators can replace the person acting as casualty, as soon as the

patient reach the first aid station. In this way we can avoid the problem with using personnel to act as casualties, thus taking them away from training in their main combat skills. In addition, there are virtual reality systems for triage training. With these systems it is possible for the flight medics to prepare before they participate in live training. Advanced patient simulators can be used for training advanced first aid, patient stabilization and in flight care. With these simulators the paramedic get continuous feedback on the treatment from the simulated patient's vital signs.

Command and Control Staff

The command and control staff needs training in order to minimize the time for management of different resources. They must also be able to coordinate units in time and space. Finally, they need to monitor the ongoing MEDEVAC missions and plan ahead for the next ones. Wargaming and command post training systems can support training in mission planning and coordination. Modeling and monitoring of the internal and external communication of the command post provides feedback during an after-action review (Thorstensson et al., 2001).

Team Training

To achieve maximum performance the members of the MEDEVAC team—pilot, navigator, flight medic, command and control personnel—must learn to work together. Modeling and simulation can support this training by providing part-task trainers, for example with mock-ups of airframes and simulated medical equipment. In this way, the majority of the phases of a MEDEVAC mission can be trained on the ground.

Taskforce Training

The last phase of training before going out in action is full scale applied tactical training. This type of training should hold a realistic scenario and include all aspects and cooperating units of a real MEDEVAC mission. Computer-supported taskforce training (Jenvald, 1999) is an approach that uses modeling, simulation and visualization to record the facts from an applied tactical training exercise and construct a multimedia model of it (Morin, 2002). This representation makes it possible to present a replay of the MEDEVAC mission during an after-action review both to provide the big picture of the mission and to present details regarding critical factors of the mission.

Medical Related Simulations Available

Some modeling and simulation tools and devices currently available for the training of MEDEVAC flight crews, flight medics, command and control staffs, and medical task forces include the following:

Combat Trauma Patient Simulator (CTPS). CTPS incorporates commercial and government off-the-shelf products to train US military medical combat trauma teams to handle casualties that may result from the battlefield, a natural disaster, or acts of terrorism. This distributed, medical simulation system provides training in the care and tracking of an injured person from an instructor-generated wound to a student-determined outcome. The system includes a casualty-collection point, ground and air evacuation modes, a battalion aid station, a forward surgical team with a mobile operating room and a combat support hospital. A congressionally funded research and development effort, CTPS is sponsored by the US Department of Defense and managed by STRICOM. Figure 2 shows an air ambulance crew during training.

UH-60 Medical Suite Trainer (UH-60 MST). MST is the first hands-on training system that provides operational and functional task training in the UH-60 and HH-60L Air Ambulances. The system consists of a dimensionally correct, full replica cabin, a fully operational medical interior kit, simulated on-board oxygen system, external rescue hoist for patient loading, and an instructor control station with pilot controls (Pettitt & Norfleet, 2002). The MST was designed and developed by DEI Services Corporation, Orlando FL. The completed training suite will be installed at the Army School of Medicine, Fort Rucker AL in February 2003. Figure 3 illustrates the UH-60 MST concept.

Human Patient Simulator (HPS) and Emergency Care Simulator (ECS). The HPS computer-interfaced medical teaching tool is based on a lifelike replication of a human. Driven by mathematical models of human physiology and pharmacology, nearly anything that can happen to a real patient can be simulated and tailored in pre-scripted event scenarios. The patient's cardiovascular, pulmonary and metabolic characteristics and responses are modeled, as are the interactions of various drugs. A data recorder allows the instructor to assess performance with its continuous, time-based record of patient physiology and student interventions. The ECS is a simpler, easily accessible and more portable version of the HPS. ECS is designed to provide the same symptoms and reactions and can be up and running in less than 15 minutes. HPS and ECS are products of Medical Education Technologies Inc. (METI) of Sarasota FL (Anton, 2002). Figure 4 shows a medical unit employing a human patient simulator.



Figure 2: An air ambulance crew during training.

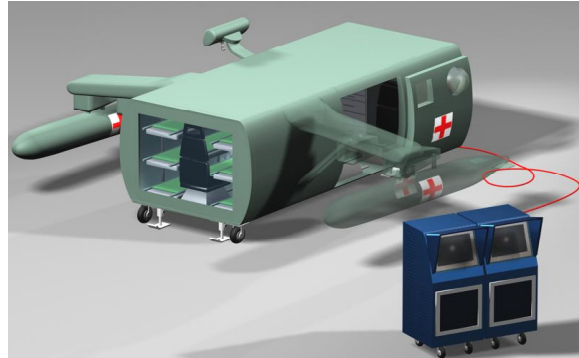


Figure 3: Artist's concept UH-60 MST.



Figure 4: A medical unit employing a HPS.



Figure 5: VirtualEMS trauma patient simulation.

VirtualEMS. Research Triangle Institute (RTI) located in Research Triangle Park, NC has developed the VirtualEMS to provide realistic scenarios and practice for emergency care training. Configurable scenarios and patients are presented through use of a virtual trauma scene and medical toolkits. The caregiver can navigate the scene, interact with the virtual patient, use the medical devices, administer medications, monitor diagnostic data, and perform interventions. VirtualEMS guides the user through standardized medical protocols followed by challenging and complex scenarios. User interactions and physiological data are recorded for after action reviews. (Kizakevich, 2002). Figure 5 shows a screen dump from the VirtualEMS trauma patient simulation system.

Discussion

MEDEVAC missions are carried out during different types of operations. These operations impose different requirements on the MEDEVAC crew regarding the type of threat and the type of injuries that will meet the MEDEVAC team during their mission (see Table 2). In addition, the environment in which the MEDEVAC team must work will vary depending on the operation type.

Regardless of the organizational level of training we can identify important common methodological aspects in order to provide efficient feedback to the trainees. Documentation, analysis and feedback are crucial for evaluating training. The three phases of trainee feedback can be described as:

1. *Documentation.* The first phase is the ability to observe and document the current situation. Data collection can be performed with both automated and manual means. Automated methods are good for recording large amounts of data, for example flight routes and communications. Manual methods with the use of observers are suitable to record unit activities and professional procedures.
2. *Analysis.* The second phase includes analysis of the documented description of the team and the activities. Now it is possible to relate and compare the goals and mission statement for the team with the analysis results.
3. *Communication.* The third phase support reflection during the After-Action Review (AAR) and forms the basis for formulating the lessons-learned from training. The lessons-learned can be used in the next stage of training as well as for preparing new trainees for this specific training stage (Jenvald, Morin & Kincaid, 2001).

These phases are applicable in all levels of training and for all categories of trainees. However, the implementation of the phases in different situations may vary.

The approach to identify training needs and training opportunities presented in this paper is based on the phases of a MEDEVAC mission. Modeling and simulation can provide training to meet existing and new needs in the MEDEVAC area – for example due to new types of missions, new patient evacuation platforms and increased requirements on joint capability.

The MST, for example, provides a significant improvement in access to casualties, and provides an on-board production of oxygen overcoming logistics obstacles. The power distribution system, crew seating and interior configuration provides for an increased standard of care when needed, through the use of portable equipment. The external hoist provides extraction capability without loss of valuable cabin space and the environmental control system and medical lighting provide a suitable environment for medical care. The camera data collection system which allows the instructor full access views of the cabin even under night vision goggle (NVG) conditions, provides an excellent source of evaluation data for after action reviews. In short, MST provides the required, realistic medical care environment to train more highly skilled providers.

The blending of advanced mannequins – such as the HPS and the CTPS – allows collective trauma care training for participant caregivers at every station in the identification/evacuation/treatment process. Target groups include casualty collection points, ground evacuation medics, battalion aid station personnel, forward surgical teams, air ambulance crews, and combat support hospital personnel. New medical simulation tools can be put into the hands of personnel and medical cross-training can be accomplished. Complex problem scenarios such as those associated with natural disasters or terrorism or battlefield casualties can be trained through task force levels.

Virtual simulations such as VirtualEMS can provide immersive desktop training that can hone individual medical assessment and decision-making skills with instant feedback as to the appropriateness of the decision with no harm done to the virtual patient. This type of training can be done at any time and skill levels can be programmed accordingly.

This paper has highlighted just a few of the modeling and simulation tools currently available. There exists an on-going research effort to improve them and to make them even more realistic, accessible and user-friendly as well as to develop new simulation methods, tools and devices to meet today's expanded and complex mission requirements.

Conclusion

A successful MEDEVAC training methodology employed to meet today's multi-faceted mission requirements uses sophisticated and realistic simulation tools and devices that

can be integrated into realistic scenarios. However, there is a need to develop even better medical personnel training methods. The US Army alone trains over 100,000 medics every year. The civilian community shares the need as well. To best train medics to treat, stabilize, and provide in-flight medical care to the critically injured or ill while being transported by air ambulance during peacetime or combat operations requires a combination of modeling and simulation tools.

The need for training is perpetual. Acquiring new skills and new knowledge, sustaining proficiency and practicing to achieve higher levels of competence must be inherent activities in any emergency response organization, whether military or civilian. At the same time, new techniques and methods are announced that, allegedly, enable effective and efficient training to achieve the training goals. Thus, the need for methods to analyze training needs and devising training programs will grow. In this paper we have reviewed the phases of a MEDEVAC mission and identified different training needs. We have also described different means of training for different personnel categories based on several modeling and simulation opportunities.

MEDEVAC is a crucial function for our field units. It has to be reliable during all types of operations. There is a need for more simulation-based tools for planning, rehearsal, training, testing and evaluation of MEDEVAC response. Computer simulations can provide an inexpensive and efficient training technique, replacing field exercises and field units during a training event, allowing response teams to be better prepared for future battle and civilian casualty situations.

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