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SIMULATION MODELING REQUIREMENTS FOR DETERMINING SOLDIER TACTICAL MISSION SYSTEM EFFECTIVENESS

Eric S. Tollefson
Michael J. Kwinn, Jr.
Phillip G. Martin

Operations Research Center of Excellence
United States Military Academy
West Point, NY 10996, U.S.A.

Gregory L. Boylan
Bobbie L. Foote

Department of Systems Engineering
United States Military Academy
West Point, NY 10996, U.S.A.

ABSTRACT

In order to maintain an edge during this time of unprecedented technological growth, the Army must field Infantry soldier systems quickly; however, the cost of doing so without some assessment of utility is quite high. Therefore, the acquisition community must estimate the operational impact of proposed systems with an increasing degree of accuracy. For this, the Army has turned to combat simulations. However, the focus in the past has been on larger battlefield systems and unit-level analyses. Additionally, Infantry soldier models require unprecedented fidelity in terms of the soldier entity and his environment. As a result, the simulation representation of the individual soldier on the battlefield has not kept pace with other representations. In this paper, we discuss our identification of the unique simulation requirements for modeling the Infantry soldier as a system of systems in support of acquisition decision making.

1 INTRODUCTION

The Army acquisition community requires high-resolution simulations that represent the Infantry soldier in enough detail to estimate the operational effectiveness of soldier weapons and equipment. Specifically, they need a tactical combat simulation capability for Infantry missions at the level of platoon and below with resolution down to the individual soldier (a platoon consists of 30-40 soldiers in 3-4 squads). The simulation capability must accept, as input, scenarios and soldier system characteristics. It must model the functions of the soldier in a tactical environment, and provide, as output, the measures of effectiveness (MoEs) used to evaluate the soldier systems. The simulation(s) will provide the analytical capability to support Program Executive Office (PEO) Soldier decision making.

Our research demonstrates that an appropriate method to define the requirements for such a simulation is a combination of common systems engineering tools, specifically a functional decomposition combined with input-output analyses. That systematic methodology provided us the means to identify detailed simulation requirements.

In this paper, we begin with a description of the problem background. Following that, we briefly lay out our methodology. The main portion of the paper follows with a discussion of the resulting requirements identified during our analysis, organized by soldier function. We then describe the direction of our continued work and conclude with a summary of our key findings.

2 BACKGROUND

Over the last decade, the United States Army has recognized the utility of using simulations as part of the acquisition process, and has named this initiative Simulation and Modeling for Acquisition, Requirements, and Training (SMART). The SMART program "involves rapid prototyping using M&S [modeling and simulation] media to facilitate systems engineering so that materiel systems meet users' needs in an affordable and timely manner while minimizing risk (Army Model and Simulation Office 2002)." This initiative brings with it the challenges of identifying the appropriate simulation packages.

PEO Soldier is the Army organization responsible for the acquisition of most of the weapons and equipment carried and used by the Infantry soldier. One of their primary goals, and the focus of this study, is to identify a simulation package that will provide the means to quantify the platoon-level operational effectiveness of a new system or component. Thus, the simulation must be at the resolution of the individual soldier while providing aggregate measures at the platoon level to facilitate system comparison and to justify the cost or additional weight of the system.

To date, various Army agencies and contractors have recognized the need for such a simulation and have made considerable efforts to address the problem. From our observations, their efforts to identify requirements follow one of two approaches. The first is an upgrade-based approach, wherein the recognition of a unique requirement drives changes to an existing (legacy) simulation to meet that need. This is an iterative approach that leads to a continual upgrade cycle, often resulting in numerous concurrent versions of the same software, and is limited by the architecture and design of the software. This process rarely yields a comprehensive set of requirements that fully identifies an organization's needs, a valuable product itself.

The second is a characteristics-based approach. In this approach, an organization identifies its requirements based on the characteristics used to evaluate the system of interest. When we began this project, we too attempted to derive the requirements in this way. Although this approach does result in a comprehensive set of requirements, it has some drawbacks. One is that the characteristic itself may not be well-defined or translate well into simulation requirements. For instance, a commonly-used term for a capability improvement of modern soldier systems is their ability to enhance a soldier's *situational awareness*. Not only is the definition of this term not widely agreed upon, its broad implications make it hard to decompose into requirements. A soldier's situational awareness directly affects, and is directly affected by, other high-level characteristics like mobility, lethality, and survivability, which themselves overlap for many of the soldier's functions. That interdependence complicates the logical decomposition into simulation requirements and is the primary reason we chose another method. Even more, the diverse group of simulation stakeholders may not easily understand the terminology of the resulting product.

3 METHODOLOGY

We employed a third approach for this study, based upon the Systems Engineering and Management Process (SEMP), taught in the Department of Systems Engineering at the United States Military Academy (USMA) as the standard problem solving methodology (McCarthy, McFadden and McGinnis 2003). The first phase of the process is Problem Definition. This phase involves many tools and techniques to convert the initial problem statement received from the client into a revised problem statement that fully articulates the client's true need. Such techniques include system decompositions, stakeholder analyses, functional decompositions, analyses of system inputs and outputs, futures analyses, and Pareto-type analyses. The analyst then transforms the required system functions into objectives and measures to evaluate those objectives. This *value system* represents the values of the primary stakeholders and provides a basis to evaluate future alternative solutions. For our study, we wished to have, at the end of the Problem Definition phase, a set of simulation requirements that meet PEO Soldier's need.

We focused on modeling the individual Infantryman, and began by decomposing all of the functions that the soldier executes in the performance of his mission. We then organized those functions into a hierarchy by working from both top-down and bottom-up to ensure completeness. Since the intent of the final set of requirements is to define a simulation capable of comparing alternate materiel solutions, we decomposed down to subfunctions that either have a bearing on the performance of the soldier system, or allow for differentiation between alternative systems.

Once the hierarchy was complete, we focused on each function and identified the inputs transformed by the function and the outputs produced. As an example, we will describe the soldier function of choosing a target to engage. Inputs into this decision include the soldier's own location, the target location, the threat presented by the target, the soldier's perceived probability of hitting the target, other targets, the terrain, the weather, his sector of responsibility, his location in the formation, etc. The primary output is a target choice, which may be an input to the actual engagement function. Attributes of the soldier would include his training level, experience, doctrine, rules of engagement (ROE), role in the unit, etc. All of these attributes affect how the soldier transforms his inputs to an output and may be unique to that soldier. Upon completion of the overall hierarchy, we then converted the functional hierarchy into simulation requirements. For a more detailed discussion of the methodology used, along with its advantages and challenges, see Tollefson, et al. (2004).

4 RESULTS

Early in our analysis, we discovered that the simulation model requirements flowed from two primary needs: the need for realism and the need for a tool to compare candidate soldier tactical mission systems (STMS). The simulation model has to produce valid outcomes based upon the inputs. This fact is certainly not unique to our study, but is the goal of all combat simulations. But how much realism is required? Resource and technology constraints dictate that we define an appropriate level of fidelity. The answer to that question depends primarily upon the purpose of the simulation. The purpose of our simulation is to provide a decision aid for comparing STMS configurations and distribution. Therefore, the simulation model must represent those inputs and outputs affecting or affected by the system being considered, while still producing a valid result. Otherwise, unique aspects of the systems being compared will not factor into the simulation output, potentially resulting in an uninformed decision. This is currently the case in existing simulations and the reason PEO Soldier commissioned this study.

Any comparison between systems must consider the system's performance with respect to its desired characteristics. Examples of STMS characteristics include mission capability, survivability, lethality, mobility, protection, communications, situational awareness, and trustworthiness. Trustworthiness itself encompasses reliability, availability, maintainability, sustainability, and usability. The simulation model, then, must provide measures of the system's performance in terms of those characteristics.

Measures used to evaluate the predicted outcomes for one or more characteristics are called measures of effectiveness (MoEs). For instance, a common MoE used to evaluate lethality is the total number of enemy kills. Thus, a higher total number of enemy kills represents a higher degree of lethality. That MoE may depend upon a large number of measures of performance (MoPs). MoPs are lower-level measures that quantify the performance of a specific piece of equipment or human task. Using the lethality example, the total number of enemy kills may be a function of the following MoPs: weapon rate of fire, accuracy, reliability, human aiming error, target location error, etc. It is quite apparent that weapon reliability, a MoP that directly affects the total enemy kills, also directly affects system trustworthiness. This is an example of the interdependence that led us to decompose by function.

Interestingly, our combination of functional decomposition with input-output analyses actually improved our understanding of the desired performance outputs (or MoEs). By identifying the inputs and outputs of every function, we were also identifying MoPs. Since those MoPs directly affect MoEs, we were able to identify unexpected sources of performance contribution that we would have missed using other methods. Thus, for a comparative analysis, our results give PEO Soldier a clearer picture of how their individual systems contribute to the effectiveness of the soldier system of systems. The following sections discuss, in some detail, the primary soldier functions.

4.1 Requirements for Soldier Representation

At the highest level of our functional decomposition, the two main functions of the soldier are deciding and acting. We use the term *decide* to indicate any mental process performed by the soldier. The six primary decide functions we identified are: assess the situation, make sensing decisions, make engagement decisions, make movement decisions, make communications decisions, and make enabling decisions. The latter five correspond to the five primary act functions: sense, engage, move, communicate, and enable. We will discuss the identified functions in the following sections, beginning with a discussion of attributes.

4.1.1 Attributes

As we mentioned in the methodology section, a simulation must represent the soldier entity using a complete set of attributes that affect the entity's performance of a function (or transformation of inputs to outputs). These attributes can act as inputs or controls. For example, attributes acting as controls may be rule sets for making a decision, a general knowledge base drawn upon by cognitive processes, or physical constraints affecting performance. Additionally, these attributes can be affected or changed by the process itself. For instance, movement can reduce the soldier's energy level, operations can increase his experience level, and equipment damage can change its physical and performance characteristics. Attributes can be entered directly or be fed by engineering level simulations.

We group the soldier attributes into three categories – mission, personal, and equipment. Mission attributes reflect the soldier's knowledge about his mission and how he is expected to accomplish that mission. They generally apply to all soldiers in the unit. Personal attributes reflect characteristics of the soldier himself, and may, or may not, vary from soldier to soldier. While the simulation may take such data from engineering level models of human performance, these attributes should still factor into the mission level simulation by affecting soldier performance. Personal attribute subcategories include physical, physiological, psychological, mental, and readiness.

Equipment attributes reflect characteristics of the equipment, weapons, or clothing worn by the soldier. They may differ by soldier, depending on the type of equipment he is carrying, but are normally constant for a particular piece of equipment. The actual attributes greatly depend on the specific type and model of equipment being represented. These include weapons and ammunition, sensors, communications, clothing, and other equipment. It is these attributes that PEO Soldier would be interested in altering to reflect different types of equipment. Therefore, these attributes must be modeled explicitly.

4.1.2 Assess the Situation

This first main function serves as a primary driver for practically all soldier decision-making and actions, and may well be the most difficult to model. Within the context of this paper, the assessment function involves the basic aspects of what the military commonly refers to as METT-TC analysis. Such an analysis centers on the soldier's assessment of his Mission, Enemy situation, Terrain (referred to as *environment* in this paper), Troops available (such as *friendly situation* or knowledge of supporting and adjacent units), Time available, and Civil considerations. For the purposes of brevity, any further use of METT-TC directly refers to the soldier's assessment of the situation.

Wherein PEO Soldier's requirements are concerned, this assess function is critical. Not only does an effective assessment obviously enhance the soldier's situational awareness, it has direct and indirect impacts in other areas, such as lethality and mobility (e.g., soldier assessment of weapons/equipment needed to complete mission). In fact, many of the proposed capability enhancements of PEO

Soldier systems aim to provide the soldier with improved means for collecting and analyzing information critical to his situational assessment. Accordingly, any simulation that seeks to offer comparative analysis between PEO Soldier systems must certainly model how those systems enhance or detract from the soldier's ability to assess the situation. It is also important to recognize that the soldier's assessment phase never truly ends. In fact, throughout the duration of a particular mission, the soldier is constantly updating his assessment based on physical observations, encounters, and external data fed to him through various conduits (analog or digital communications, voice/hand signals from a squad-mate, etc.).

4.1.3 Sense and Make Sensing Decisions

On the asymmetric battlefield of today, soldiers at every level make decisions based on a *sensing* of the battlefield. In fact, much, if not all, of what Infantry soldiers do on the battlefield involves varying degrees of sensing. This includes the specific functions of searching, acquiring and tracking targets. Accordingly, the soldier's sensed perception of the battlefield plays a critical role in his decision processes and resulting actions.

PEO Soldier systems directly address this function by providing sensing capabilities that affect inputs into the decision cycle. For example, PEO Soldier systems, such as thermal weapon sights, night vision devices, GPS systems, and other video systems, enhance the soldier's ability to detect, acquire, identify, and track potential targets. Similarly, such systems enable the soldier to refine his METT-TC assessment more efficiently. Logically, by virtue of the enhanced capabilities they provide, these system components will affect soldier decisions. Therefore, any potential simulation must model those decisions and how they are affected by sensing equipment.

PEO Soldier products also serve to enhance the soldier's physical ability to observe the battlefield. Most are designed specifically for improving his ability to see throughout the EM spectrum – visual, image intensification, infrared, and thermal; however, improvements to the soldier's ability to use his other senses are probably not far into the future. In that vein, we must consider both the soldier's natural and technologically-enhanced sensing capabilities. Additionally, for the sake of realism, the simulation should model the soldier's ability to detect other cues, e.g. hearing movement or weapon reports, or making observations based on fortuitous glances that may shift his attention.

Ultimately, the simulation should reflect how a particular soldier system affects the soldier's sensing capabilities. For example, a future system may propose a fully enclosed helmet. Does this enhance or detract from natural sensing methods (e.g. does it impede peripheral vision and thereby create a tunnel effect; does it dampen sound to such an extent that soldiers are more susceptible to surprise, etc.)? Soldier systems could be differentiated based on how they overcome such problems and to what extent they enhance natural sensing capabilities.

4.1.4 Engage and Make Engagement Decisions

Any simulation must explicitly model the soldier's ability to engage enemy forces, since it is one of the soldier's primary functions. As with any function, however, the actual act of engaging a target cannot occur without some form of decision process associated with it, no matter how hasty. While the decisions rely heavily upon the weapons and equipment that the soldier is carrying, the unit assets at his disposal, and his means of bringing those assets to bear, they are also impacted by the quality of the soldier's METT-TC assessment and his sensing decisions/actions that led to the target in the first place.

PEO Soldier has made great strides in weapon and sensor enhancements that improve engagement decisions. As addressed under the sense function, enhanced sensory capabilities enable the soldier to acquire, identify, and track targets more efficiently. Advanced communications and digital equipment, coupled with GPS and laser targeting devices, will allow the soldier to call upon networked fires with shorter response times and greater accuracy.

Such capabilities, while affecting the soldier's engagement decisions, will also have the obvious additional impact of affecting the actual act of engagement. Products such as aiming lights, the Integrated Laser White Light Pointer, Multi-Function Laser System, and the Sniper Night Sight should enable the soldier to engage targets with greater accuracy, thereby influencing such measures as the probability of kill, probability of hit, etc. Accordingly, any simulation seeking a comparative analysis of soldier systems must effectively address both the engagement decision cycle and the resulting engagement process.

4.1.5 Move and Make Movement Decisions

Any soldier system will have some impact on his ability to move, including navigating, changing posture, and changing location through various means of movement. Accordingly, any simulation must address the effects, positive or negative, a system has on these functions. For example, while weapons and sensor enhancements certainly increase a soldier's lethality, all of these additional pieces of equipment must be carried. This may have a counter-balancing effect on lethality in that more weight translates to a more fatigued soldier. Thus, the modeling requirements must capture the impacts of the physical weight and arrangement of the systems on soldier movement, navigational capabilities, and signature (his detectability).

Through many of its products, PEO Soldier seeks capabilities that 1) do not physically impede movement and 2) enhance the soldier's ability to navigate. For example, navigational decisions are aided by GPS equipment, the Helmet Mounted Display (HMD), or the Commander's

Digital Assistant (CDA). For comparative analysis, a simulation must represent the benefits of those types of equipment in conjunction with comparative cases (e.g., navigational errors caused by the use of only a map and a compass). On a smaller scale, these decisions encompass soldier movement towards cover and concealment.

As previously discussed, the soldier's continual METT-TC assessment triggers the decide/act cycles associated with these functions. The information shared via the CDA, HMD, and communication equipment can aid the soldier in making movement decisions, thereby necessitating representation. Again, the simulation should model any mistakes made in the absence of these devices, as well as the choice of movement methods to avoid detection (slower, crouched, deliberate, etc.).

The actual physical functions of moving from one location to another are not directly aided by current PEO Soldier programs, with the exception of some climbing aids for urban operations (UO). However, future soldier equipment could feasibly include exoskeletons and other muscular aids that would serve to enhance basic human movements and strength. Regardless, the weight of the equipment carried and worn by the soldier affects these functions. Consequently, in order to differentiate between soldier tactical mission systems (STMS), the simulation should model the impacts of equipment on soldier movement rates, degrees of motion on his joints, limitations in his fine motor skills, etc.

Lastly, the soldier's selection of a particular posture (standing, kneeling, lying down) has a great impact on the outcome of an engagement, both in terms of the accuracy of the firer and the exposure of the target, as well as the exposure of the firer to returned fires. The obvious impacts of such a choice, coupled with the fact that current PEO systems afford soldiers the ability to fire from a reduced exposure position, require representation in any simulation.

4.1.6 Communicate and Make Communications Decisions

The ability to communicate serves as a vital battlefield multiplier for the soldier since it enhances situational awareness, lethality, and protection. Accordingly, the simulation model must consider communication capabilities above, below, and lateral to the soldier. It must consider issues like integration and interoperability with other battlefield digital systems, both mounted and dismounted. It should model enhancements in range and non line-of-sight (NLOS) capabilities. In the case of Land Warrior, communications include not only radios, but the HMD and CDA.

Communication is critically important to current and future soldier systems. In addition to the ability to transmit voice data, soldiers can transmit digital data as well, allowing for a greater exchange of information. Much of the information sent and received by personnel and devices (e.g., information transmitted via satellite or robot) supports soldier decisions on the battlefield and thereby influences his actions. Therefore, it is important that the simulation capture these decisions and functions in order to represent the soldier accurately.

Transmitting includes all types of communication such as verbal, hand-signaling, writing, typing information into a CDA, etc. While a plethora of communication modes creates redundancy, the devices must compete for bandwidth. Bandwidth constraints or system overload translate to lost information and degraded situational awareness. The simulation must represent these transmissions and the associated impacts on the soldier. The simulation must also model communication with soldier-controlled systems like unmanned aerial vehicles (UAVs) and robots, as well as the time required to communicate (e.g., time required to type and send a written order or graphics).

As with transmissions, receiving communications from other soldiers or data devices is critical to the success of PEO Soldier-equipped entities. It cannot be assumed that all information available to soldier will be received. Therefore, the distinction between what is received by the soldier and what is not is critical for simulation.

4.1.7 Enable and Make Enabling Decisions

Enabling functions reflect the soldier's ability to operate in his surroundings and perform common tasks critical to survival and the performance of the other four main functions. Thus, these actions *enable* the soldier to engage, move, communicate, and sense, either directly or indirectly, as well as *operate* in the basic human sense.

In the course of battlefield operations, the soldier will engage in various decide/act cycles that support one or more other functions. Such cycles include the altering of terrain, load manipulation, and basic human operation. In choosing to alter terrain, the soldier acts either defensively to counter a threat or offensively to gain advantage. These alterations might include digging a fighting position to enhance protection or clearing fields of fire to enhance his ability to engage. If moving, he may decide to breach through or move an obstacle in his path by cutting wire, removing mines, etc. These decisions are especially important in urban operations (UOs), in which soldiers must open doors and windows, move furniture out of their way, etc. Because any STMS might positively or negatively impact this ability, the simulation must model it

Similarly, the soldier will make decisions concerning his load based on mission necessity. For instance, upon making contact, the soldier will probably drop his rucksack until the conclusion of the engagement in order to enhance his agility and mobility (thereby enhancing lethality). Likewise, when a unit moves into a pre-assault position, they may leave their rucksacks and unnecessary equipment behind, under guard, until the mission is complete. Other load manipulations might include choosing to pick up an enemy weapon if ammunition is low, or shifting equipment around to make some available for use (e.g., pulling equipment from the rucksack or putting unnecessary equipment into it). Any system will affect the soldier's ability to perform these necessary functions and will likely come with various configuration options. Therefore, at a minimum, the most basic and common of these decisions should be modeled in a simulation.

Other enabling functions include conducting bodily functions (eating, drinking, and sleeping), performing first aid to self and others, and performing equipment maintenance, resupply, and repair. These functions affect how the soldier and his equipment operate and so require representation, to some degree, in the simulation model.

4.2 Requirements for Other-Than-Soldier Representation

The previous section discussed our decomposition of the functions of the Infantry soldier, since that was the focus of our effort. However, our requirements would be incomplete if we did not mention other aspects of the simulation model that must be considered. In some cases, the functional requirements imply a modeling capability that should be expounded upon due to its importance. In other cases, we integrate requirements of numerous functions into a cohesive topic.

4.2.1 Representation of the Environment

Representation of the environment is a tremendously complex issue. Our methodology provides a means to determine environmental requirements by identifying inputs and outputs of each function. If some aspect of the environment is an input into a function, then it should be represented to model that function accurately. Additionally, if an output of a function is an effect on the environment, the simulation should model that as well. The requirements and discussion here only touch upon the more important aspects of this representation as they relate to the requirements of PEO Soldier.

At the highest level, the simulation must be capable of representing any type of environment in which the soldier might operate – urban, desert, jungle, swamp, forest, plains, mountains, arctic, and littoral. Within the environment, the simulation must model various aspects of the terrain. Terrain relief, combined with the weight of the soldier's equipment, will affect his ability to move. Relief also impacts whether a one entity can see and, in the case of direct fire weapons, engage other entities. The model should represent the effects of vegetation on round, fragment, and shrapnel trajectories. Additionally, soldiers seek cover from enemy fire behind trees, and concealment from detection behind various types of vegetation. Therefore, those aspects should be modeled. However, the simulation need not necessarily represent each individual plant explicitly. Instead, a random draw to determine whether the soldier can find such cover or concealment can occur based on the type of environment. This implies that the model does not require 3-D representation.

One of the key aspects of terrain that must be modeled is urban terrain, as statistics point to an increased likelihood of military operations in that type of environment. The accurate modeling of structures is critical for assessing the effectiveness of any system in an urban environment. The structure models should be able to represent interior and exterior characteristics, with multiple rooms, multiple floors, construction material properties, windows, doors, and furniture. It should also have attributes that allow the assessment of weapons effects on the various components of the structure. It should affect the soldier's ability to communicate within and between buildings. Additionally, the simulation must model other urban features: vehicles, infrastructure (electric and phone cables; poles; gas, sewer, and water lines; etc), paved areas, businesses, and general urban layout (roads, alleys, blocks, industrial parks, yards and fences, etc).

Another major aspect of the environment is the climate, which can have a significant impact on soldier and equipment performance. Weather conditions (e.g., temperature, humidity, pressure, wind, and precipitation) affect equipment reliability and performance, as well as the soldier's ability to perform tasks. Light conditions affect his ability to sense surroundings. Man-made conditions, such as battlefield obscurants like smoke and dust, chemical and biological contamination, and illumination devices also have a tremendous impact on the soldier and so require representation.

The simulation environment should be dynamic. This requirement reflects the ability of the simulation to alter the terrain and climate during a single run and would account for the effects of the soldier and his weapons, such as blast craters, damage to structures, fire damage, and changes to vegetation from deliberate soldier action. Dynamic climate allows for changes as the day progresses (e.g., temperature, humidity, and barometric changes) and changes due to the effects of soldier and his weapons.

4.2.2 Representation of Other Entities

We did not go into the same detail for other types of entities as that discussed for the representation of the individual soldier. For the required simulation capability, we are concerned primarily with the representation of the soldier. Therefore, models only need represent other entities to the degree that the soldier will observe or interact with them.

For instance, there may be less need to represent an artillery piece explicitly, only the fires request process, the incoming rounds, and their effects. However, for a tank, the simulation may have to model its physical and vulnerability characteristics, its capabilities, and a realistic portrayal of its behavior. The same is true of aircraft, personnel carriers, trucks, and other systems the soldier may physically encounter on the battlefield.

The simulation must also represent higher headquarters and lateral units, but only to the degree necessary for communications and directives purposes. For instance, if the platoon leader is attempting to communicate with his company commander on the company net, then the traffic from all company elements on that net should be simulated to ensure a realistic representation of delay. Other representations of higher headquarters might include the ability to attach company mortars or an extra squad, for example.

4.2.3 Representation of Network-Centric Warfare

Network-centric warfare is implied in the discussions of many of the soldier functions; however, we will discuss it here as one integrated topic, focusing on its effects on the target engagement process. Clearly, this characteristic of warfare must be represented in any simulation that might be used to evaluate future soldier systems.

The target engagement process can be broken down into five distinct functions, called battlefield information functions, which are search/detect, identify, track/target, engage, and assess. The responsibility for the performance of these functions is shifting away from the individual soldier to a host of systems distributed throughout the battlefield. Thus, sensors may search/detect, identify, and track/target potential enemy targets, engagement logic may trigger an unmanned weapons platform to engage, and sensors may assess the effects of the engagement (Kwinn 2001).

The soldier may fill any of the battlefield information function roles as either a sensing or engagement platform; however, he may no longer fill all of the roles. Thus, the discussion of soldier functions does not alone capture the network-centric process. While the soldier's core functions may capture his role in that process, the simulation must account for the digital transfer of information between the soldier and other network platforms and how that information affects the functions of the soldier and those platforms.

4.2.4 Representation of System Reliability and Power Requirements

Technological advances in equipment invariably create increased power requirements, integration issues, and special maintenance and repair issues. Hence, it becomes necessary to model equipment reliability and power systems.

The modeling of reliability should account for the failure rates of each of the components and how the various potential component failures would affect the system as a whole. This does not require explicit modeling but perhaps an association with probability functions for potential system errors and probabilistic estimations of the repair times required for those failures. Likewise, the system failures should affect the soldier's ability to perform certain functions and require the soldier to switch to an alternate method of performing that function, if available.

The simulation should represent power requirements based on the mission, power load, and power source capacity, as well as the ability to resupply. Furthermore, the modeled power requirements coupled with reliability should account for the effects of the environment on system attributes.

4.2.5 Representation of Weapons and Ammunition Effects

While our functional discussion implies this type of representation, it merits special mention. In short, the simulation must represent all types of weapons and ammunition that the soldier may carry or encounter on the battlefield.

For direct fire weapons, the simulation should represent kinetic energy weapons, non-lethal weapons, electromagnetic energy weapons, and other types of weapons delivered via soldier, vehicle, or aircraft-mounted platforms. The model should consider area and point firing, as well as the various firing modes (single shot, burst, and fully automatic). Similarly, it must include all types of direct fire ammunition (to include non-lethal types).

Indirect fire weapons necessitate similar representation. The model should represent lethal and non-lethal weapons delivered via soldier, towed, vehicle, or aircraft-mounted platforms and should accurately depict the characteristics of the rounds they fire. These characteristics include the particular type of round (high explosive rounds (air burst, point detonated, and delay), white phosphorous, illumination, smoke, smart munitions, etc.), as well as the time to fire, time of flight, and round adjustment requirements. Likewise, the model should account for chemical and biological weapons, their means of delivery, and their effects on the environment and the soldier.

In conjunction with the actual direct and indirect fire systems, the simulation should also model their key firing characteristics (either explicitly or implicitly). Important direct fire parameters include maximum effective range, rates of fire, bias (variable and fixed), random error, and probabilities of hit, kill, and incapacitation for all possible weapon-munition-target groupings. These must also account for all weapon-sensor pairings, as they will affect the aforementioned probabilities. Important indirect fire parameters include range, lethal radius, ballistic error, dispersion, aim error, target location error, and probabilities of kill and incapacitation due to fragments and blast effects.

The representation of weapons, ammunition, and explosives must include their effects on targets (humans with various levels/types of protection, structures, vehicles, vegetation, terrain, other objects). Such representation should include effects based on the part of the target struck and the level of protection in that area. Injuries should be affected by treatment, time, and the environment. These effects include not only the effects of hitting the target, but also suppressive effects on personnel nearby (varied suppression duration and level based on the ammunition characteristics, the soldier's protection, and his state of mind).

5 CURRENT EFFORTS

After having completed the extensive requirements analysis discussed above, we moved into Phase II of the SEMP – Design and Analysis. In this phase, we generated potential simulation solutions to PEO Soldier's needs. Next, we eliminated any alternatives that were clearly infeasible using constraints uncovered during Problem Definition. We then used our evaluation measures to model the remaining alternative solutions by evaluating each alternative against those measures.

Phase III of the SEMP, Decision Making, consisted of scoring and comparing the alternatives based upon our value system. The resulting comparison, sensitivity analyses and cost-benefit analysis led us to conclude that PEO Soldier should pursue the modification of and linkage between the following simulations: Combat^{XXI}, the Infantry Warrior Simulation (IWARS), and Objective One Semi-Automated Forces (OneSAF). We presented our results and recommendation to PEO Soldier on 14 May 2004. They agreed with our recommendation and we are now in the final phase of the SEMP (Implementation).

Currently, we are conducting joint presentations with PEO Soldier to selected stakeholders in the DoD analysis and Infantry soldier system acquisition communities to generate community buy-in to our solution. With consensus, we can move forward with implementation. Key to implementing our solution, we must convert our functional requirements into simulation specifications that will allow simulation managers and programmers to implement PEO Soldier requirements into their software. To do that, we must determine how to divide the requirements among the simulations, either through direct modification or through a linkage. Factors that might affect this parsing of requirements, especially in cases where more than one option exists, include the planned and existing capabilities of the simulations, simulation architectures, cost of implementing the requirement, usefulness to the simulation proponent, basis for the requirement, implementation time, and synergy with other requirements. Thus, we must attempt to optimize the benefit by minimizing the costs, both financial and other.

With the initial agreements complete, a set of specifications, a comprehensive plan to implement those specifications, and initial timelines, costs, and resources determined, we will begin execution of our recommendation. Our role will then switch to that of monitoring progress, renegotiating agreements due to unexpected changes, and quality assessment.

6 CONCLUSIONS

The obvious question raised is how does our approach differ from similar ongoing efforts? The answer to this question is threefold. First, through a detailed and methodical process, we have more accurately and completely delineated the battlefield functions performed by the Infantry soldier. With that, we have considered future functions and the need to represent them when the time comes. Second, our results more clearly and accurately reflect the interdependence between soldier functions with respect to lethality, mobility, situational awareness, and survivability as well as between those measures of combat effectiveness themselves. This is significant insofar as it facilitates a more complete and useful comparative analysis between alternatives. Third, our results demonstrate that a good simulation aimed at yielding quantitative and qualitative comparative results need not possess three-dimensional fidelity. Rather, a two-dimensional model supported by appropriate probabilistic measures addresses the need more directly and fully.

PEO Soldier must be able to evaluate the platoon-level operational effectiveness of the Infantry soldier systems managed by its acquisition programs. By concentrating on the functions of the Infantry soldier, we were able to identify the unique simulation requirements necessary to evaluate the combat effectiveness of the wide array of PEO Soldier weapons and equipment. Those requirements led to a well-received recommendation and movement towards implementation.

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AUTHOR BIOGRAPHIES

ERIC S. TOLLEFSON is an Assistant Professor and an Analyst in the Operations Research Center at the USMA, West Point. He has served in various positions, including platoon leader, company commander, and as a staff officer. He holds a BS in Engineering Physics from USMA and a MS in Operations Research from the Georgia Institute of Technology, May 2002. His email address is `<fe0398@usma.edu>`.

GREGORY L. BOYLAN is an Instructor in the Department of Systems Engineering at the USMA, West Point. He has served in various positions including platoon leader, company executive officer, rifle company commander, and staff officer. He holds a BS in Environmental Science from USMA and a MS in Industrial Engineering from the Georgia Institute of Technology. His email address is `<fg8977@usma.edu>`.

MICHAEL J. KWINN, JR., Ph. D. is an Associate Professor and the Director of the Operations Research Center of Excellence at USMA. His military assignments include Fort Bliss, TX, Germany, Colorado, and South Korea. He earned a BS from USMA in 1984, a MS in Systems and Industrial Engineering from the University of Arizona in 1994 and a PhD from the University of Texas Red McCombs School of Business in 2000. His research interests include optimization and simulation as well as combat system requirements development and assessment methodology development. He is a member of the Board of Directors for the Military Operations Research Society. His email is `<michael.kwinn@usma.edu>`.

BOBBIE L. FOOTE, Ph. D. is Senior Faculty in the Department of Systems Engineering at the USMA. Dr. Foote served 32 years as a faculty member at the University of Oklahoma in Industrial Engineering. He was a two-time director of the department and was also associate director of the Oklahoma Center For Integrated Design And Manufacturing located at Oklahoma State University in Stillwater as well as Professor of Industrial Engineering at OU. After retirement he worked with a team to re-engineer corporations such as Compaq. He joined USMA in 2001 where he teaches and conducts research in statistics, modeling and optimization as applied to Army problems. His email address is `<bobbie.foote@usma.edu>`.

PHILLIP G. MARTIN is an Instructor and an Analyst in the Operations Research Center at the USMA, West Point. He has served in various positions, including platoon leader, company commander, and as a staff officer. He holds a BS from USMA and a MS in Industrial Engineering from the Georgia Institute of Technology, May 2003. His email address is `<fp7163@usma.edu>`.