Proceedings of the 1993 Winter Simulation Conference
G.W. Evans, M. Mollaghasemi, E.C. Russell, W.E. Biles (eds.)

VIRTUAL REALITY AND ANALYTICAL SIMULATION OF THE SOLDIER

Victor E. Middleton
Robert T. McIntyre III

Simulation Technologies, Inc.
Suite 748, 111 Building
111 West First St.
Dayton Ohio 45402

John O'Keefe IV

US Army Natick Research, Engineering, and Development Center
ATTN:SATNC-AA
Kansas ST
Natick MA 01760-5015

ABSTRACT

Historically, the individual soldier has received short shrift in the world of military modeling and simulation, which has been more concerned with the analysis of major weapons platforms. The altered focus of today's military is shifting this emphasis; shrinking force structures and changing missions are accenting the role of the individual dismounted soldier. At the same time, rapid growth in computing power and new technologies such as virtual reality have greatly increased our ability to provide high resolution modeling of the soldier. This paper explores the evolution of soldier simulation resulting from integration of traditional constructive models with these new technologies.

1 INTRODUCTION

This paper examines the introduction of virtual reality and related technologies such as synthetic environments into conventional, established military models and simulations. The focus will be on the present and potential impact of virtual reality on initiatives in support of the Soldier System, which is the Army's new Research and Development (R&D) concept for developing the next generation individual dismounted soldier. The Soldier System views the soldier as an integrated weapon system, with unified development and functionality of all the soldier's equipment, training, and doctrine.

Soldier System Modeling and Simulation (M&S) is achieving new importance in an era of novel and expanded roles for armed forces subject to ever increasing budgetary constraints. In one sense, virtual reality simulations can be viewed as an evolutionary goal of M&S, with M&S defining the underlying mathematical models to ensure that virtual reality and/or associated synthetic environments provide a realistic and robust simulation. In this context, the problem of representing the Soldier System in a synthetic environment is the same problem that has been faced by military modelers historically. This paper will examine the issues involved in such representation: requirements, the potential of current tools and emerging technologies to meet those requirements, and the potential impact of virtual reality technologies across the spectrum of Soldier System initiatives, from equipment R&D, to training the soldier to use this equipment, and ultimately to operational applications on the battlefield.

2 BACKGROUND - THE SOLDIER SYSTEM

Historically, equipment for the soldier has been developed through separate, distinct initiatives. Research and development analysis tools have followed this division, with separate models for ballistic weapons, individual protection, etc. While each of these efforts may have been carefully planned and implemented with respect to their individual goals, the end result was still an overwhelming collection of disparate items. The current recognition of the need to treat the soldier as a "Soldier System" comes from the realization that the soldier's weapons, protective gear, and other supplemental equipment must function together as a system, and hence must be designed, evaluated, and maintained as a system.

R&D analysis must support the soldier's mission by facilitating design, construction, test, and fielding of the soldier's equipment. Classical models, with their emphasis on particular aspects of the battlefield (e.g. combat systems, performance degradation, thermal stress) do not provide a comprehensive understanding of a unit's (or an individual's) ability to perform a combat mission.

3 BACKGROUND - THE AUTHORS' PERSPECTIVE

The US Army Natick Research Development and Engineering Center (Natick), supported by Simulation Technologies, Inc. (STI), is currently developing a model architecture, the Integrated Unit Simulation System (IUSS), to provide a comprehensive analysis environment for the evaluation of Soldier System's survivability and effectiveness. The IUSS is designed to parallel the evolution of the Soldier System concept by combining historically disparate models of different aspects of the soldier and the soldier's combat systems into an integrated representation of the battlefield. The IUSS provides an open, extensible architecture for the unified representation of all aspects of the modern battlefield: threats, personnel, equipment, and environmental factors.

The IUSS is designed to accommodate bundled access to current and evolving methodologies, providing a flexible simulation package. In particular, this design facilitates the integration of new technologies such as virtual reality with traditional models. For example, the IUSS incorporates design goals to extend the concept of a graphical user interface (GUI) to a new level, allowing the user to enter a dynamic virtual world, manipulating this synthetic environment through a "natural" user interface, the NUI. Full realization of the NUI concept injects the analyst (or optimally, many analysts) completely into the simulation. The analysis paradigm now consists of simultaneously creating and exploring a new world. The NUI allows the analyst to record observations (ideally from all forms of sensory data as well as enhancements such as infrared or x-ray vision), to stop and restart the world, and to play dynamic what if games.

4 THE SOLDIER SYSTEM SIMULATION SPACE

Figure 1 shows Soldier System Simulation as a three dimensional space, bounded in two directions by the user's relationship with the simulation, and in the third by the degree of fidelity of the simulation models.

The concept of virtual reality is expanding horizons of the two user interface dimensions:

- the user world view - the level of detail the user sees, which varies from highly abstract world views expressed as stylized icons or as simple data dumps (e.g., lists of numbers), to the ideal of a multi-dimensional recreation of physical reality, simulated, sight, sound, touch, etc.
- the user/world interaction - the degree to which the user can affect the simulated world, which varies from simple passive observation of the simulation as its executes, to allowing the man-in-the-loop to dynamically change simulation parameters during execution, to the ultimate goal, of making the user a dynamic simulation object, one of the primary sources of input data driving the simulation.

Up to now, the technological challenges associated with interjecting the user into the simulation (e.g., simulation refresh rate, physical reaction sensors and data input devices) have forced trade-offs, increasing capability in one dimension meant decreasing it in another. Added to this is the problem of the third dimension of the Simulation Space, the fidelity or degree of resolution in the underlying mathematical models of the soldier and the soldier's environment. Even without user interface complications, the difficulties involved with high resolution modeling of the individual dismounted soldier are immense. Natick's current efforts to produce the IUSS are in part aimed at providing enabling methodologies to support both high resolution classical analysis and future developments applying virtual reality and synthetic environment technologies to a variety of Soldier System applications. Some of these applications, as discussed below, will require extending current capabilities along all three of these dimensions.

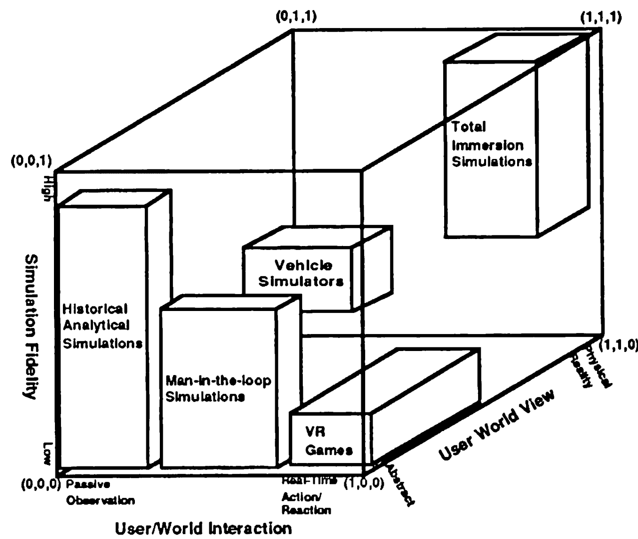

Figure 1 The Soldier System Simulation Space

5 COMBAT SIMULATIONS AND SIMULATORS

Much of the impetus behind the development of the IUSS came from a recognized deficiency in the ability of current models to provide high fidelity representation of the individual dismounted soldier. This deficiency is partially the result of historical emphasis on weapon systems and platforms as opposed to the individual soldier, but it is also due to the fact the high fidelity simulation of the individual soldier is very hard to do, requiring the organization, supervision, and application of large volumes of data (many of which are fragmentary, incomplete or worse, inconsistent) and the modeling of many complex, inter-related, and in many cases poorly understood phenomena.

This aspect of the problem is not getting any easier. The analysis community must manage an ever-increasing volume of raw data describing soldier performance, soldier system equipment attributes, the expected threat and the soldier's mission. Furthermore, the community is charged with the task of not only maintaining these data, but also applying them to perform the analyses required in support of the Soldier as a System. One of the drives behind integrated analysis environments with a more natural, more accessible user interfaces, is the need to support all of these data management and application functions, and to expedite the performance of required analysis, while at the same time providing high fidelity simulation to represent the dismounted soldier at historically unobtainable levels of resolution.

Just as with constructive simulations, Combat Simulators were first developed to support vehicles as weapon platforms, and their initial application was training operators. Recent efforts (e.g., SIMNET) have focused on inserting such simulators as players in large scale war games. Unfortunately, these simulators incorporate at best only very rudimentary representation of the individual dismounted soldier. Since that soldier's performance may have a decisive effect on the course of the battle, it is necessary to include some measure of that performance in these simulations. To date, the solution has been to try and aggregate results from more detailed models as input parameters to the large war game simulations. This is not satisfactory because it does not allow for dynamic change in soldier status in response to battlefield conditions, and because there simply does not exist a large enough data base of battlefield stressor effects to accurately reflect what happens to the individual soldier.

Ultimately the solution will require a real-time model of the individual soldier, acting in concert with other war game entities (tanks, planes, etc.). While this solution is at present a long way from realization, current efforts into virtual reality and associated human performance research are fulfilling some of the requirements needed to achieve this goal.

6 TECHNICAL CHALLENGES

Placement of the dismounted soldier in a synthetic environment requires:

1. High resolution environmental simulation - representation of the physical environment, terrain, weather, battlefield hazards, at an adequate refresh rate and changing in response to the soldier's actions.
2. Physiological tracking - update of soldier position, vital signs, and anthropometric limitations in response to the battlefield through some "natural" interface.
3. Virtual equipment - representation of the soldier's load, e.g., protective equipment, night vision goggles, communications gear, etc.

Among the technical challenges to be faced are the adequate representation of: the battlefield environment, the soldier's interaction with that environment as he/she moves about the battlefield constrained by the hazards and stressors present, and finally the development of virtual prototypes of soldier system equipment - computerized instantiations of equipment concepts.

One possibility, the approach taken by Natick's IUSS, is to implement analysis scenarios as a series of time and event-driven model calculations, driven by the dynamic interaction of the scenario "objects", each of which is supported by underlying mathematical models of its basic processes. These objects are modular in nature, with encapsulated functions which permit easy update/replacement of their math models as new representations become available. The objects interact with one another in three basic update phases. The first of these defines the basic features of the battlefield environment, calculating time-dependent challenge profiles for chemical agents, conventional munitions, or other battlefield stressors. The second determines individual soldiers' exposure to these stressors and calculates an appropriate level of human response by relating stressor effects with psycho-physiological condition. Specific levels of each hazard or stressor are correlated with constraints on human performance. In phase three, these constraints on the soldier are compared with mission task requirements to determine the soldier's capability to perform mission tasks. Individual performance measures are in turn aggregated to unit mission measures of effectiveness, which are the ultimate metrics of concern to the IUSS target audience.

7 RECONFIGURABLE INDIVIDUAL SOLDIER SYSTEM ENVIRONMENT

The IUSS and the concept of virtual reality come together as enabling technologies for the Dismounted Warfighting Battle Lab. The goal of the Battle Lab is an integration of technologies to provide seamless transition from live fire exercises to totally constructive war games, as appropriate to a specific application. Nothing will ever replace the requirement for soldier training under actual field conditions; a measure of the utility of M&S is the degree to which they can replicate the "look and feel" of field conditions. The Battle Lab goal is adroit use of M&S to supplement, augment, or supplant, actual field experience as needed.

Through such degrees of augmentation or substitution, M&S provides the capability to quickly (and cheaply) reconfigure the soldier's environment. This is fast becoming a critical technology capability as the scope of potential soldier missions expands. Today's armed forces have to be ready to go literally anywhere in the world on a moment's notice. If the Battle Lab is to provide them with the training doctrine and technologies required to maintain their combat advantage, it must be able to replicate potential battlefield environments in any theater of operations.

8 FACTORS WHICH MUST BE INCORPORATED

The Soldier System synthetic environment must incorporate a representation of what has been called the "3-D relationship" among soldier equipment, human performance, and the battlefield environment. This term was first used at a meeting of the Technology Base Executive Steering Committee (TBESC) Working Group on Soldier System modeling needs in the fall of 1992. The 3-D relationship, as shown in Figure 2, is a fundamentally task-based framework amenable to quantification in an object oriented system like the IUSS.

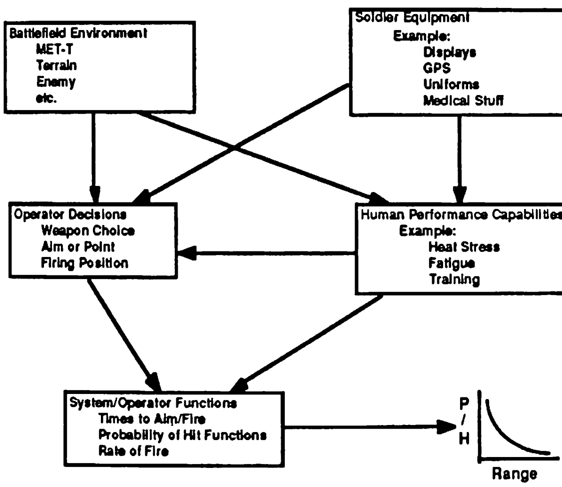

Figure 2 Soldier System 3-D Relationship

This 3-D relationship paradigm is currently being applied to tasks defined according to the Battlefield Operating Systems Tasks (BOS-T) functions (as described in US Army Training and Evaluation Plans (ARTEPs). Implementing the paradigm with respect to those tasks, furthers the development of the Battle Lab's seamless integration concept. Simulated tasks and task performance which follows the Army's training and operations procedures, provides the soldier user with an environment which corresponds to his/her world view.

9 VIRTUAL REALITY SIMULATION FOR SOLDIER EQUIPMENT R&D

To compete for a share of today's limited military budget, R&D equipment developers must be able to provide a priori demonstration that their products will provide positive benefits in line with required investment. The ability to provide a virtual prototype of such equipment, and exercise that prototype in realistic battlefield scenarios furnishes a demonstration with considerable credence. In addition to illustration of concept benefits, virtual prototypes can also promote user acceptance and hone requirements definition by allowing the user virtual "hands-on" experience with proposed equipment design. This opens a communication channel between user and developer and injects valuable user feedback into early stages of the product definition process.

Simulations, which incorporate synthetic environments, also allow the R&D analyst to explore equipment effects on Soldier System performance across a broad spectrum of potential operating theaters and proposed mission scenarios. This supports traditional cost benefit and trade-off analyses with increased realism and validity. The virtual prototype concept is not limited to actual equipment. It can also be used to explore operational issues such as the effects of changing doctrine and tactics. Furthermore, in keeping with the philosophy of the Soldier System, virtual/synthetic environments support analysis of integrated effects and inter-factor synergisms.

10 VIRTUAL REALITY SIMULATION FOR SOLDIER TRAINING INITIATIVES

An important element of the Soldier System concept is this idea that equipment does not stand alone, that it must be viewed in concert with training and operational issues. Virtual prototypes of proposed equipment can easily be converted into equipment simulators, and used either as stand-alone training devices or incorporated into larger scale systems following the seamless integration concept being developed for the Battle Lab and other wargaming applications.

Synthetic environment capabilities can be used to augment field exercises through the simulated addition of factors, such chemical or biological threat agents, which may be difficult or impossible to actually experience in peace-time exercises. Using a Virtual Reality engine as an exercise controller supports data capture for exercise review, and if desired a given exercise may be computer re-generated to points of interest and replayed for additional insights or to reinforce particular training points. As is the case with current vehicle simulators, virtual prototypes and synthetic environments provide easy access to training media for the retention of perishable skill sets.

11 VIRTUAL REALITY SIMULATION FOR OPERATIONS

As virtual reality tools mature, they will migrate to the operational world. Ideally, virtual equipment simulators would be interchangeable with their operational counterparts in training and exercises. A measure of success for such substitutions would be a sort of Virtual Reality Turing Test where operators would be unable to distinguish between real world data inputs to their equipment and the data supplied by the synthetic environment.

The logical progression from training to real world operations begins with the use of virtual reality simulations in staging areas for mission rehearsal and planning purposes. Such models can be adapted for field exposition of options and to aid in the commander's decision process. Finally, in order to achieve satisfactory realism, analytical simulations will have to incorporate models and algorithms for the enhancement of model resolution through the extrapolation of incomplete data and the filtering of noise or inconsistent data. These same methodologies should prove useful in support of field data collection and interpretation for intelligence functions.

12 SUMMARY

Natick, and other DoD organizations cognizant of the enormous potential of virtual reality and associated technologies, are actively pursuing the development of these technologies. This development, is in fact, following a parallel (and in some cases overlapping) track with the current evolution of more classic M&S methodologies. As an example, Natick began development of the IUSS in response to a recognized need for high fidelity simulation of the Soldier System to support R&D initiatives. This development faces many of the same issues of resolution, data requirements, and potential application as does the development of virtual reality simulations. It is only natural to allow cross-fertilization of these efforts, and in so doing, greatly leverage the return on R&D methodology investment.

Virtual reality is currently a hot research technology; achieving particular prominence for potential applications in training, distributed wargaming, and other "demonstration" oriented applications. While these high profile applications excite the imagination and are undoubtedly responsible for much of the current interest in the field, it is possible that the greatest return will come from the use of virtual reality as the next step in the evolution of constructive simulations, the successor to the graphical user interface as the "natural" paradigm for man-machine interaction. This natural user interface could be the key to unlocking the potential of Soldier System simulation by providing access to the general user community, removing M&S from the category of arcane lore practiced by a small number of specialized analysts, and placing it instead with the growing category of automated tools available to (and profitable for) the complete spectrum of military and civilian users.

ACKNOWLEDGMENTS

The work described herein was supported primarily under contract DAAK60-91-C-0125 with the US Army Natick Research Development and Engineering Center. Preliminary findings have been presented at both the Aerospace Applications of Virtual Reality and Simulations Technology Synthetic Environments Conference and at the 61st Annual Military Operations Research Society Symposium. The opinions expressed are solely those of the authors and do not represent any official US Army position.

REFERENCES

US Army ARTEP 7-8-MTP, *Mission Training Plan for the Infantry Rifle Platoon and Squad*, dated September 1988).

Vic Middleton, *Integrated Unit and Soldier Systems Survivability and Effectiveness Evaluation Roadmap*, dated January 1992).

Paul F. Gorman, *Supertroop VIA I-Port: Distributed Simulation Technology for Combat Development and Training Development*, dated August 1990

AUTHOR BIOGRAPHIES

VICTOR E. MIDDLETON is a mathematician under contract to Simulation Technologies, Inc. and is responsible for the development of simulation algorithms for the Integrated Unit Simulation System.

ROBERT T. MCINTYRE III is a senior analyst with Simulation Technologies, Inc. and directs the development and application of the Integrated Unit Simulation System.

JOHN A. O'KEEFE IV a former U.S. Army Major, is a senior operations researcher with the Concepts Analysis Division Advanced Systems Directorate of the US Army Natick Research Development and Engineering Center and is the contract monitor for development of the Integrated Unit Simulation System.