INTRODUCTION TO MILITARY TRAINING SIMULATION: A GUIDE FOR DISCRETE EVENT SIMULATIONISTS

Ernest H. Page

Roger Smith

The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, VA 22102, U.S.A.

STAC Inc.
3481 Woodley Park Place
Oviedo, FL 32765

ABSTRACT

An overview of military training simulation in the form of an introductory tutorial is provided. Basic terminology is introduced, and current trends and research focus in the military training simulation domain are described.

1 INTRODUCTION

Let's say you're a discrete event simulationist. You were raised on the likes of (Banks, Carson and Nelson 1984; Fishman 1973; Franta 1977; Law and Kelton 1982; MacDougall 1987; Shannon 1975; Schriber 1974; Tocher 1963) and you have a penchant for the event scheduling world view, although you've been known to dabble in process interaction. One day you find yourself discussing the topic of simulation with a representative of a well-known defense contractor. Ten minutes into the conversation, you are surprised at the difficulty you are having communicating. You each seem to be using terms unfamiliar to the other, and where common terms exist, you have the uneasy feeling that there are nuances of definition not being accounted for. The conversation ends and you spend the next few moments wondering whether you actually know as much about simulation as you thought you did.

Our objective in this tutorial is to spare the intrepid discrete event simulationist those moments of doubt by providing a gentle introduction to the current practice of military training simulation. We introduce some of the common terminology, and briefly highlight a few of the current thrusts in research, development and practice. Be aware, however, that this presentation merely scratches the surface of a large topic. The world of *military simulation* is very broad, and training applications are but a part – albeit an important part – of it. Likewise, any legitimate treatment of *military training* would fill volumes and is well beyond the scope of this effort. Even limiting our focus to *military training simulation,* space limitations dictate that some important and interesting topics are omitted here. We have tried to include bibliographic references and URLs most useful to the reader interested in furthering his or her study.

The presentation strongly reflects a U.S. military training simulation perspective, since that is the environment the authors are most familiar with, and no attempt has been made to differentiate military training simulation by national approach. To our knowledge, however, many of the concepts described here correspond directly or approximately to military training simulation concepts outside the U.S.

The remainder of the paper is organized as follows. Section 2 provides an introduction to some common terminology and definitions relevant to military training simulation. A brief historical perspective and a discussion of the current trend toward systems interoperability is provided in Section 3. Section 4 identifies a few of the current research issues in military training simulation, and conclusions appear in Section 5.

2 TERMINOLOGY AND TAXONOMY

A logical first step in familiarization with the military training simulation world is an introduction to the *language* of military training simulation. If you are unfamiliar with U.S. Department of Defense (DoD) in general, the first thing you will realize is that there is no shortage of acronyms in the DoD vernacular. In this article, we attempt to keep acronym usage to a minimum for readability, but be advised that familiarity with the acronyms is critical to your successful entree into the military simulation arena. A good source for acronym and terminology definitions is (U.S. Department of Defense 1997b).

The second thing you'll discover about DoD is that while quite often definitive sources for terminology exist, both usage and other published sources do not always match

the definitive. Perhaps this should not be surprising. The DoD is a very large organization; it is probably not uncommon that the views expressed by someone affiliated with a large organization do not always completely and accurately reflect the official position of the organization itself.

Within the DoD, simulation is applied to support a variety of missions, including: (1) *training,* (2) *analysis,* (3) *acquisition,* (4) *mission rehearsal,* and (5) *test and evaluation.* Our focus is limited to the application of simulation for training, although much of what follows applies to each of these missions.

2.1 Basic Definitions

In the DoD setting, simulation is generally referred to in the context of the acronym "M&S," which stands for *modeling and simulation* or *models and simulations* depending on the context of its use. Officially (U.S. Department of Defense 1997b):

Model is a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

Simulation is a method for implementing a model over time.

Modeling and simulation refers to the use of models, including emulators, prototypes, simulators, stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably.

Simulator is: (a) a device, computer program, or system that performs simulation; (b) for training, a device which duplicates the essential features of a task situation and provides for direct human operation.

War Game is a simulation game in which participants seek to achieve a specified military objective given pre-established resources and constraints; for example, a simulation in which participants make battlefield decisions and a computer determines the results of those decisions. Syn: constructive simulation; higher order model.

Although the merits of these definitions may be argued, they represent the official position of the DoD as of December 1997. Of course, it is quite possible to find alternate definitions either in publication or use. For example, in many settings, the *de facto* definition for simulation is that simulation encompasses everything other than war itself. This definition is reflected in some of the categories of simulation described below.

So the DoD lexicon is not without its ambiguities and contradictions. As another example, the same source that seems to preclude Monte Carlo simulation, which inherently contains no notion of time, from the class of things called simulation, offers this definition (U.S. Department of Defense 1997b):

Monte Carlo simulation. A simulation in which random statistical sampling techniques are employed such that the result determines estimates for unknown values.

This is a mine field you will have to learn to navigate. Experience has shown that the fastest way to derail a meeting is to introduce a discussion on definitions. Caveat discrete event simulationist!

In addition to these basic concepts and definitions, there are a variety of ways that simulations are differentiated within the DoD. We review a few of these taxonomies below.

2.2 Virtual, Live and Constructive

Although perhaps becoming less common in its usage, the *virtual, live, constructive* classification scheme is officially described as (U.S. Department of Defense 1997b):

Virtual simulation refers to a simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills (e.g. flying an airplane), decision skills (e.g. committing fire control resources to action), or communication skills (e.g. as members of a C4I team).

Live simulation refers to a simulation involving real people operating real systems.

Constructive simulation refers to a simulation that involves simulated people operating in simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes.

Essentially, virtual simulation refers to the use of simulators, live simulation to rehearsal or practice with "go-to-war" systems, and constructive simulation refers to classical computerized simulation models. As noted in (U.S. Department of Defense 1997b) this classification system is, at best, flawed:

> The categorization of simulation into live, virtual, and constructive is problematic, because there is no clear division between these categories. The degree of human participation in the simulation is infinitely variable, as is the degree of equipment realism. This categorization of simulations

also suffers by excluding a category for simulated people working real equipment (e.g. smart vehicles).

As noted in Section 3, one of the goals of current DoD M&S initiatives is the creation of *synthetic environments* that represent the "seamless" integration of virtual, live and constructive simulations within a common simulated battlespace.

2.3 Logical Time and Real Time

Another means by which simulations may be distinguished relates to their treatment of time. Simulations that explicitly model the passage of time and allow the rate of its advancement to be dictated by the granularity of simulated events may be described as *logical-time simulations.* Simulations that do not *model* time but rather use the real clock values to drive their execution may be described as *real-time simulations.* This differentiation is best illustrated by an example.

The Corps Battle Simulation (CBS) is a ground combat model used to train Army and Joint staffs at a variety of levels. CBS is primarily written in SIMSCRIPT II.5 and falls into the category of logical-time simulation. The Modular Semi-Automated Forces (ModSAF) is also (primarily) a ground combat model, but used to train at lower echelons than CBS. ModSAF is written in C, and falls into the category of real-time simulation. Both CBS and ModSAF are *interactive* models, i.e. they permit user input to occur while the model is running. Both CBS and ModSAF have the capability to pace their rate of execution at some ratio to real time. For CBS this is accomplished by posting specialized events on the event list. For ModSAF this is accomplished by specifying its frame rate. The critical difference between the two (justifying their separation into different categories) comes when the amount of computation required to compute the next state exceeds the amount of real time available before the next state *should* occur. If at time $t = 10$ seconds it requires 3 seconds to compute the state for time $t = 11$ seconds, what do you do?

Fundamentally, no system can *guarantee* complete, simultaneous faithfulness to both simulation time and real time. In situations like the one described here, a choice *must* be made by the simulation. Logical-time simulations, like CBS, observe simulation time. It takes however long it takes to compute the next state. (As an aside, CBS has a capability to attempt to catch up by running faster than the desired rate over a user-specified interval.) Real-time simulations, like ModSAF, degrade or abandon next-state computation, if necessary, in order to maintain synchrony with real time.

The difference between logical-time simulations and real-time simulations is also apparent in their code. Logical-time simulations have the classical discrete event or continuous simulation data structures and algorithms. Real-time simulations resemble real-time systems – their execution is measured by hertz frequency, and they are typically interrupt driven.

2.4 Entity Level and Aggregate Level

Military simulations are often differentiated based on their inherent level of abstraction. If the primary objects represented in the simulation are collections of doctrinally identifiable military assets, e.g. a tank battalion, then the simulation is referred to as an *aggregate-level simulation.* If the primary objects represented by the simulation are singular military objects, e.g. a tank, a soldier, the simulation is referred to as an *entity-level simulation.*

Historically, entity-level simulations have been used to train at lower military echelons, e.g. Platoon, Company, and aggregate-level simulations have been used as the basis for training at higher military echelons, e.g. Brigade, Division. A current trend is toward the development of singular simulation systems that train at all echelons. The costs and benefits of this approach are yet to be fully understood.

3 MOVING TOWARD A PARADIGM OF INTEROPERABILITY

Historically, military simulations and simulators have been applied in fairly narrowly focused contexts to achieve specific sets of goals. If no single system could fulfill the objectives of a given training exercise, a new system was constructed or the objectives of the exercise modified to accommodate the capabilities at hand. In the mid-to-late 1970s, the idea of connecting training devices, namely simulators, began to take shape.

The first meaningful attempt to interoperate military simulators was the Simulator Networking (SIMNET) project initiated by the Defense Advanced Research Projects Agency (DARPA) in 1983 (Allusi 1991; Ground and Schwab 1988). SIMNET was an effort to interoperate tank trainers to support unit (collective) training, and represented advances in a number of areas including, image generation technologies, low-cost simulator design, and networking technologies.

The success of SIMNET spurred the desire to describe general purpose protocols to support a wide range of network-based training applications. This effort resulted in the formulation of two unique sets of protocols which we briefly describe below.

3.1 Distributed Interactive Simulation

The Distributed Interactive Simulation (DIS) protocols became an IEEE standard in the spring of 1993 (Pullen and Wood 1995; Voss 1993). The primary mission of DIS is (University of Central Florida 1993, p.3):

> ...to create synthetic, virtual representations of warfare environments by systematically connecting separate subcomponents of simulation which reside at distributed, multiple locations ... The property of connecting separate subcomponents or elements affords the capability to configure a wide range of simulated warfare representations patterned after the task force organization of actual units ... Equally important is the property of interoperability which allows different simulation environments to efficiently and consistently interchange data elements essential to representing warfighting outcomes.

The DIS protocols and concept of operations are closely tied to those of SIMNET. Generally, DIS simulations are entity-level, real-time simulations. Communication in a DIS environment is based on the Protocol Data Unit (PDU), a bit-encoded packet for communicating entity state and other types of information identified as useful within the protocol, e.g. weapons fire events. A process known as *dead reckoning* is used to reduce the number of *entity state* PDUs introduced onto the network during runtime, by allowing entity state extrapolation between updates. Using dead reckoning, each simulation maintains a low fidelity model of the objects owned by other simulations and uses this model to update the position and orientation of those objects based on the last reported value. For each object a simulation owns, it also maintains the same low fidelity representation. When the low fidelity and high fidelity representations differ by some predetermined threshold, the owning simulation broadcasts a PDU containing the actual (high fidelity) values.

DIS has been used as the protocol underlying numerous warfighting experiments and Advanced Concepts Technology Demonstrations (ACTDs), most notably, the Synthetic Theater of War (STOW) family of experiments.

3.2 The Aggregate Level Simulation Protocol

Like the DIS protocols, the Aggregate Level Simulation Protocol (ALSP) also has its roots in SIMNET, but ALSP was targeted toward support for the interoperation of aggregate-level, logical-time simulations (Page, Canova and Tufarolo 1997; Weatherly, Wilson and Griffin 1993; Weatherly et al. 1996).

Prior to 1990, DARPA was working to improve the efficiency of simulation-based training through better hardware infrastructure. Their emphasis on networks and portable computer centers made it possible, so they hoped, for warfighters in Europe and Korea to train at their home bases rather than travel to the Warrior Preparation Center (WPC) in Einsiedlerhof, Germany or the Korea Battle Simulation Center (KBSC) in Seoul, Korea. About the same time the Berlin Wall came down, the DARPA vision of distributed simulation was put to the test by the Allied Command Europe (ACE) '89 exercise. It failed. As is often the case, the exercise did not fail in areas where attention was paid (the network, switches, more rugged computers, etc.) but in areas where attention was lacking – the simulation software. The complexity of distributed computation was greatly underestimated. As the Commander of the Warrior Preparation Center later said, "The smoke got too thick and the mirrors got too heavy."

Many of the software problems observed in ACE '89 were traceable to an inconsistent perception of the time and state relationships within the distributed simulation, and disagreement about how simulations should cooperate in modeling combat objects. ALSP provides an ASCII-based message-passing protocol and software infrastructure that coordinates the advance of simulation time, enforces adherence to a common object model of the shared simulation state, and arbitrates contests over the right to modify that shared state.

Fielded in the spring of 1991, the ALSP Joint Training Confederation (JTC), which currently consists of eight Joint and Service simulations, has been successfully employed to support numerous major, large-scale, Joint training exercises, including the annual Ulchi Focus Lens, Prairie Warrior and Unified Endeavor exercises (Miller and Zabek 1996).

3.3 The High Level Architecture

The High Level Architecture (HLA) has been proposed and developed to support reuse and interoperation of simulations across the U.S. Department of Defense (Dahmann, Fujimoto and Weatherly 1997). The HLA represents both a generalization and extension of DIS and ALSP. The HLA is defined by three components:

- a common model definition and specification formalism (U.S. Department of Defense 1988a);

- a collection of services describing the HLA runtime environment (U.S. Department of Defense 1988c); and

- a set of rules governing compliance with the architecture (U.S. Department of Defense 1988b).

The HLA is intended to have wide applicability across the full range of defense simulation applications, including

those used to support training, analysis, mission rehearsal and acquisition. The HLA is designed with a high degree of flexibility, permitting arbitrary mixtures of fidelity and resolution.

At the heart of the HLA is the notion of a *federation.* A federation is a collection of *federates* – simulations and other systems – that interoperate using the protocols described by the architecture. A Federation Object Model (FOM), constructed in accordance with the formalism identified in (U.S. Department of Defense 1988a), provides the model specification and establishes a contract between the federates regarding the nature of the activity taking place during federation runtime. Federation execution is accomplished through an HLA Runtime Infrastructure (RTI) which is an implementation of the infrastructure services defined in (U.S. Department of Defense 1988c). In addition to defining services for the RTI, the HLA Interface Specification defines services that must be implemented by federates.

In a typical federation execution, a federate joins the federation, indicates its operating parameters (e.g. information the federate will provide *to* the federation and information it will accept *from* the federation) and then participates in the evolution of federation state until the federate departs the federation, or the simulation terminates. FOM data is provided to the RTI at runtime, enabling the infrastructure to provide a level of enforcement with respect to the "information contract" that the FOM represents.

In a 1996 memorandum signed by the U.S. Undersecretary of Defense for Acquisition and Technology Dr. Paul Kaminski, the HLA is endorsed as the standard for all U.S.DoD M&S (U.S Department of Defense 1996). The HLA standard supersedes both ALSP and DIS and all DoD M&S efforts must comply with the HLA, receive a waiver, or be retired by 2001.

4 CURRENT ISSUES IN MILITARY TRAINING SIMULATION

The need for, and demands on, military simulation are continually increasing. Driven largely by fiscal necessity, an increasing pressure to employ simulation is driving exploration into new methods for modeling combat activities. DoD is currently focusing significant attention in the areas of domain architectures, common terrain representation, behavior representation, multiresolution modeling and synthetic natural environments.

4.1 Domain Architectures

A *domain architecture* is designed to facilitate software reuse by providing a common framework for multiple projects. The Army, Navy, Air Force, and Intelligence communities are currently developing their next generation of command and staff training simulations. Each of these replaces an existing, so-called *legacy,* system that has been made interoperable with those of the other Services. Simulation sponsors, designers, and users recognize that much of the functionality of these legacy systems is similar and illustrates duplication of effort across the Services.

The Joint Simulation System (JSIMS) and One Semi-Automated Forces (OneSAF) programs are attempts to unify the next generation of Service simulations and Semi-Automated Forces simulations, respectively, to eliminate software duplication, lower development costs, provide common user interfaces, and reduce life-cycle costs for using and enhancing the systems. The JSIMS architecture attempts to isolate two distinct classes of simulation functionality (Powell 1996). The first class is domain-independent simulation infrastructure. The second class includes basic representations of simulated objects and the building blocks for creating user interfaces, and external system data exchange. This layer also manages communication with the first layer, allowing specific model builders to focus on their model rather than on the intricacies of the infrastructure for supporting those models. The OneSAF architecture, currently under development, is likely to reflect a similar separation of functionality (U.S. Department of Defense 1997a).

Programs like OneSAF and JSIMS, when viewed in the context of the HLA initiative, illustrate a seeming dichotomy in current DoD approaches to M&S. The former collection seeks to construct large, monolithic simulations that serve many audiences with widely varying objectives. The latter approach (within the context of the broader DoD M&S technical framework) suggests that small, simple, well-defined and narrowly-scoped simulations provide the basis for the application of M&S, with complex problems being addressed by the federation of multiple simulations.

Both JSIMS and OneSAF prominently tout the notion of *composability* in their architectures. So it is possible that in the end, each of these programs – HLA, JSIMS, OneSAF – may result in the reflection of a common set of modeling principles, blurring or erasing the dichotomy. But it is probably premature to make any predictions or judgements.

4.2 Terrain Representation

Military operations typically focus around physical activities on specific areas of the earth. Therefore, simulations of these activities each require a representation of this terrain. In the absence of terrain representation standards, a variety of unique and often incompatible terrain representation schemes have emerged, hindering the representation of a common terrain between multiple simulations. This

incompatibility requires that multiple databases of the same terrain be built to support multiple simulations, and introduces potential (undesired) variability in the synthetic environment between interoperating simulations.

To overcome these problems DOD has instituted the Synthetic Environment Data Representation and Interchange Specification (SEDRIS) project. Their intent is to create a common database format that completely supports the characteristics of existing databases. The principles underlying SEDRIS are that the data representation: (1) be complete, (2) support loss-less translation, and (3) be unambiguous.

4.3 Behavior Representation

Because of its complexity, behavioral modeling has traditionally been very basic. The goal has been to provide military vehicles and units with the ability to *react* to basic events in the absence of human intervention. These models allow aircraft on patrol to "decide" to return to base when getting low on fuel, rather than continuing until the aircraft falls to the ground. Ground units respond to enemy attacks by focusing firepower on the aggressor rather than blindly continuing their preprogrammed mission. Algorithms like these have been the extent of behavioral modeling for many years. However, more recent models have attempted to increase the reasoning capabilities of simulated objects. Most notable among these systems have been the Semi-Automated Forces (SAF) or Computer Generated Forces (CGF) systems. These systems allow a single operator to play the part of many vehicles or several Platoons with the aid of embedded behavioral models.

The approach taken by most CGF systems is to replicate the *product* of human decision making, rather than the *process*. Since we do not completely understand the inner workings of the human mind, it is easier to gather information about observed human reactions to certain situations than it is to represent the process of cogitation. However, recent developments in Artificial Intelligence (AI) technologies, e.g. intelligent agents, potentially offer new solutions to this problem.

4.4 Multiresolution Modeling

The notion of *resolution* in a simulation model is commonly used to describe the level of abstraction employed in the model – some measurement of the differences between the actual system under study and the model of that system. *Multiresolution* issues exist in single simulation models, but are perhaps made more acute by the system composition afforded by today's interoperability technologies. Determining meaningful "levels of discourse" between simulations federated through the HLA, for example, can

be a very difficult task. A classical example of this involves the interoperation of entity-level and aggregate-level simulations. Solutions to this problem involve aggregation and disaggregation, but these approaches are often *ad hoc* and generally require that objects have a singular level of aggregation at any point in simulation time. The problem of multiple, consistent, simultaneous, representations – at multiple levels of resolution – is exceedingly challenging.

Solutions to the multiresolution modeling problem are being sought under the DARPA Advanced Simulation Technology Thrust (ASTT) program.

4.5 Synthetic Natural Environments

An emerging approach in military simulation involves the separation of models of the environment from the physical and behavioral models constituting a simulation. Independent representations of the environment make it necessary to collect and manage a large volume of data. This data may include characteristics of the terrain surface, natural and cultural features, atmosphere, sea surface, subsurface, and ocean floor. The representation of radio and acoustic energy, chemical and biological agents, natural and man-made obscurants and nuclear effects are also considered part of the environment since these create a medium within which the objects must operate.

The collection and management of environmental data presents significant challenges, as does the validation of environmental models. Consistent environmental effects in a multiresolution simulation are particularly challenging, and are the subject of investigation within the DARPA ASTT program.

4.6 Verification, Validation and Accreditation

Within DoD, the acronym V&V is usually replaced by VV&A, where 'A' represents accreditation (U.S. Department of Defense 1997b):

Accreditation. The official certification that a model or simulation is acceptable for use for a specific purpose.

There are a number of difficulties attendant with the verification and validation of military training simulations (although many of these challenges are not necessarily unique to the arena). These include:

- Validating models in the absence of data. For example, valid models of combat performance degradation – as impacted by stress, morale, loudspeaker broadcasts, etc. – are desired, but little data exists to support model validation and data collection is nontrivial.

- Cost-effective VV&A of training simulations requires a focus on verisimilitude and a proper characterization

of the training objectives – which are often not well-formulated.

- The possibilities for negative training must be identified and accounted for.

- Interactive simulations raise additional difficulties by confounding the notion of repeatability that underlies many of the traditional V&V techniques.

- Validating real-time simulations introduces a performance aspect not present in traditional simulation applications.

In addition to these technical challenges, VV&A in the era of distributed, interoperable simulation introduces many programmatic and cultural barriers to cost-effective VV&A, such as the absence of centralized configuration management. Page, Canova and Tufarolo (1996) discuss both the technical and operational challenges to cost-effective VV&A in an Advanced Distributed Simulation setting, using the ALSP Joint Training Confederation as a case study.

5 CONCLUSIONS

The military training simulation arena is ripe with challenges. Training applications, arguably, are the primary driving force behind several of the current DoD M&S initiatives. While many of the applications and concepts employed in the military training simulation domain bear little resemblance to "traditional" discrete event simulations and discrete event simulation concepts, a synthesis of these two cultures is likely to benefit each. We are hopeful that this tutorial is a useful contribution toward such a synthesis.

ACKNOWLEDGMENTS

REFERENCES

Alluisi, E.A. 1991. The development of technology for collective training: SIMNET, a case history. The Human Factors Society, Reprinted in *A Revolution in Simulation: Distributed Interaction in the '90s and Beyond,* L.D. Voss, Virginia: Pasha Publications, Inc.

Banks, J., J.S. Carson II, B.L. Nelson. 1984. *Discrete Event System Simulation,* New Jersey: Prentice Hall.

Dahmann, J.S., R.M. Fujimoto, and R.M. Weatherly. 1997. The Department of Defense High Level Architecture. In *Proceedings of the 1997 Winter Simulation Conference,*
ed. S. Andradóttir, K.J. Healy, D.H. Withers, and B.L. Nelson, 142-149, Association of Computing Machinery, New York, NY.

Fishman, G.S. 1973. *Concepts and Methods in Discrete Event Digital Simulation,* New York: John Wiley and Sons.

Franta, W.R. 1977. *The Process View of Simulation,* American Elsevier.

Fujimoto, R.M. 1997. Zero lookahead and repeatability in the High Level Architecture. In *Proceedings of the 1997 Spring Simulation Interoperability Workshop,* Orlando, FL, 3-7 March.

Ground, D., and J.R. Schwab. 1988. Concept evaluation program of simulation networking (SIMNET). Technical Report 86-CEP345, Army and Engineering Board, Fort Knox, KY.

Law, A.M. and D. Kelton. 1982. *Simulation Modeling and Analysis.* New York: McGraw Hill.

MacDougall, M.H. 1987. *Simulating Computer Systems: Techniques and Tools,* Massachusetts: The MIT Press.

Mamaghani, F. 1998. Creation and use of synthetic environments in realtime networked interactive simulation, *Digital Illusion: Entertaining the Future with High Technology,* New York: ACM Press.

Miller, G., and A.A. Zabek. 1996. The joint training confederation and the aggregate level simulation protocol. *MORS Phalanx,* 29:24-27.

Page, E.H., B.S. Canova, and J.A. Tufarolo. 1997. A case study of verification, validation and accreditation for advanced distributed simulation. *ACM Transactions on Modeling and Computer Simulation,* 7(3):393-424.

Powell, E.T. 1996. The JSIMS architecture. *Summary Report on the 15th Workshop on Interoperability of Simulation Interactive Simulations,* Institute for Simulation and Training.

Pullen, J.M., and D.C. Wood. 1995. Networking technology and DIS. *Proceedings of the IEEE,* 83(8):1157-1167.

Schriber, T.J. 1974. *Simulation Using GPSS.* New York: John Wiley and Sons.

Shannon, R.E. 1975. *Systems Simulation: The Art and Science,* New Jersey: Prentice-Hall.

Tocher, K.D. 1963. *The Art of Simulation,* New Jersey: Van Nostrand Company.

University of Central Florida. 1993. Distributed interactive simulation standards development: operational concept 2.3. TR IST-TR-93-25, Institute for Simulation and Training, Orlando, FL.

U.S. Department of Defense. 1996. DoD high level architecture (HLA) for simulations, Memorandum signed by USD(A&T), September.

U.S. Department of Defense. 1997a. OneSAF operational requirements document. November.

U.S. Department of Defense. 1997b. DoD modeling and simulation (M&S) glossary, DoD 5000.59-M, December.

U.S. Department of Defense. 1998a. High level architecture object model template, Version 1.3, February.

U.S. Department of Defense. 1998b. High level architecture rules, Version 1.3 (Draft 2) February.

U.S. Department of Defense. 1998c. High level architecture interface specification, Version 1.3 (Draft 9) February.

Voss, L.D. 1993. *A Revolution in Simulation: Distributed Interaction in the '90s and Beyond.* Virginia: Pasha Publications, Inc.

Weatherly, R.M., A.L. Wilson, and S.P. Griffin. 1993. ALSP – theory, experience, and future directions. In *Proccedings of the 1993 Winter Simulation Conference,* ed. G.W. Evans, M. Mollaghasemi, E.C.Russell, and W.E. Biles, 1068-1072, Association for Computing Machinery, New York, NY.

Weatherly, R.M., A.L. Wilson, B.S. Canova, E.H. Page, A.A. Zabek, and M.C. Fischer. 1996. Advanced distributed simulation through the aggregate level simulation protocol. In *Proceedings of the 29th Hawaii International Conference on Systems Sciences,* Vol. 1, 407-415.

URLs

Aggregate Level Simulation Protocol (ALSP)
    http://ms.ie.org/alsp/
Defense Advanced Research Projects Agency (DARPA)
    http://www.darpa.mil/
DARPA Advanced Simulation Technology Simulation Thrust (ASTT)
    http://www.astt.com/
Defense Modeling and Simulation Office (DMSO)
    http://www.dmso.mil/
High Level Architecture (HLA)
    http://hla.dmso.mil/
Joint Simulation System (JSIMS)
    http://www.jsims.mil/
OneSAF
    http://www.onesaf.org/
Simulation Interoperability Standards Organization (SISO)
    http://siso.sc.ist.ucf.edu/
Synthetic Environment Data Representation and Interchange Specification (SEDRIS)
    http://www.sedris.org/
Synthetic Theater of War (STOW)
    http://stow98.spawar.navy.mil/

AUTHOR BIOGRAPHIES

ERNEST H. PAGE's biography appears elsewhere in these proceedings.

ROGER SMITH is the Technical Director for STAC Inc. and an Adjunct Professor at the Florida Institute of Technology. He is actively involved in designing, developing, and fielding simulations, having contributed to JSIMS, WARSIM, WIM, JSIGSIM, BLRSI, ADST, TACSIM, AWSIM, ALBAM, and others. He is very active in the simulation community, serving as the Chairman for the ACM Special Interest Group on Simulation and as a member of the editorial board of *ACM Transactions on Modeling and Computer Simulation.*