Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

STRATEGIC DIRECTIONS IN VERIFICATION, VALIDATION, AND ACCREDITATION RESEARCH

Robert G. Sargent
Panel Chair and Moderator

Simulation Research Group
Department of Electrical Engr.
and Computer Science
Syracuse University
Syracuse, NY 13244, U.S.A.

Priscilla A. Glasow

Advanced Information Tech. Center
The MITRE Corporation
1820 Dolley Madison Blvd. (W626)
McLean, VA 22102, U.S.A.

Jack P.C. Kleijnen

Dept. of Information Systems
Center for Economic Research
School of Economics
and Business Administration
Tilburg University (KUB)
5000 LE Tilburg, The Netherlands

Averill M. Law

Averill M. Law and Associates, Inc.
2601 N. Campbell Avenue, Suite 110
Tucson, AZ 85719, U.S.A.

Ian McGregor

AutoSimulations, Inc.
655 Medical Drive
Bountiful, UT 84010, U.S.A.

Simone Youngblood

DMSO
1901 N. Beauregard St., Suite 500
Alexandria, VA 22311, U.S.A.

ABSTRACT

Six simulation professionals present their views on the directions that they believe that verification, validation, and accreditation research should take. Two of the six are active verification, validation, and accreditation researchers from academia, two develop industry simulation models, and two work in verification, validation, and accreditation of military simulation models. A number of areas and topics for research in verification, validation, and accreditation are identified. It appears that application domains of simulation models affect what topics need verification, validation, and accreditation research.

1 INTRODUCTION

The purpose of this panel is to discuss the strategic directions in Verification, Validation, and Accreditation (VV&A) research. Six simulation professionals were selected for the panel consisting of two individuals (Law and McGregor) who develop industrial simulations, two people (Glasow and Youngblood) who work in the VV&A area of military (DoD) simulations, and two faculty members (Kleijnen and Sargent) who are active in VV&A research. Each individual was asked to write between one and one and one-half pages for the proceedings expressing their view of what they believe the strategic directions of VV&A research should be. Sections 2 through 7 contain these individual views. Section 8 is the summary.

2 VIEW OF PRISCILLA A. GLASOW

The question of what direction future VV&A research should take presupposes that some research has already been done and that there is a basis for promoting a particular direction for the future. Although academic institutions have made significant advances in VV&A research, as evidenced by the work of Drs. Sargent and Balci, little *research*, in the academic sense of that word, has been undertaken within the Department of Defense. I contend that the focus has, instead, been on establishing a baseline for VV&A practice across DoD, in the form of policies and procedures, rather than the conduct of scientifically rigorous research.

Research in the academic sense suggests either the development of new theory or the testing of hypotheses. For those of us trained in the quantitative tradition, research implies a systematic generation of new knowledge through the use of replicable methods. Research is a form of scientific inquiry that seeks new knowledge so that the conclusions that are drawn can be generalized to a larger context.

Although VV&A is certainly amenable to scientific inquiry, little research has been done within DoD to accurately describe the phenomena associated with VV&A, determine its contributing variables, or suggest plausible explanations why the phenomena occur or identify their causal origins. The confirmation of causality, testing of theory, and establishing of predictability as elements of scientific inquiry are not generally addressed by the DoD VV&A community. Although reams of "technical papers" have been written, many merely offer unsubstantiated opinions. Those that report on real world VV&A efforts are enlightening, but do not necessarily further the science by developing new theory or testing hypotheses using the tenets of scientific inquiry and methodological research. In short, VV&A, in the context of DoD, has primarily been an administrative and educational exercise, rather than a scientific endeavor.

There is considerable opportunity, however, for useful research to be undertaken, particularly in the study and application of rigorous verification and validation techniques. My first-hand experience in recent years reveals that reliance has too often been placed on leveraging the model developer's verification activities, rather than independent assessment of the model's code and logic. Similarly, validation efforts have often been limited to the use of less rigorous techniques, such as face validation and traceability assessment. Although these methods can provide useful insights, they are generally, in and of themselves, insufficient for assessing a model's validity.

My premise is that the DoD VV&A community can benefit from scientific research, in the purest sense of that term, into the study and application of rigorous V&V techniques. One approach for undertaking this research requires a refocusing of modeling and simulation endeavors on the users of models and simulations, rather than the developers, who often reflect a computer engineering perspective. In particular, the DoD analytical community must assume a stronger role in the development and use of models and simulations, and must serve as staunch advocates for the use of more rigorous techniques in assessing the credibility of those models and simulations. This advocacy must be enacted so that less reliance is placed upon subjective techniques and methods that do not involve rigorous data analysis. Research is specifically needed to evaluate how the practice of VV&A can benefit from a greater use of statistical methods, as well as examine the reasons why such methods have not been widely used to date.

3 VIEW OF JACK P.C. KLEIJNEN

VV&A has many facets, including philosophical and mathematical-statistical problems.

(i) *Philosophical problems*: What is *the* truth; if it exists, can human beings recognize it? Since I am not educated in philosophy, I simply refer to Plato as a starter, continuing with Kant, then on to Wittgenstein, Russell, and Popper; also see Naylor, Balintfy, Burdick, and Chu (1966, pp. 310-320).

(ii) *Statistical problems*: In practice, even quite simple simulations are not validated through correct statistical techniques. For example, at WSC '99 I discussed several case studies of trace-driven simulations that use a scatter plot of simulated versus real outputs (see Kleijnen 1999). These studies test whether this scatter plot has unit slope and zero intercept. However, Kleijnen, Bettonvil, and Van Groenendaal (1998) prove that such a test rejects a true simulation model 'too often', that is, more frequently than the prespecified type I error rate (say) α.

These examples demonstrate that VV&A of simulation models is a major challenge indeed! Currently, complex simulations are usually not validated at all, or are only *subjectively validated*; for example, animated output is eyeballed for a short while. A recent example seems the detailed 'microscopic' traffic simulations reported by Barcelo (2000).

The *military* are ahead of the civilian industry. For example, Balci (1999) presents a methodology for accreditation of simulation applications, which he developed over the last decade while working as a consultant to the US defense industry. He bases this methodology on Saaty's Analytical Hierarchical Process (AHP). Another example is the validation study performed for the Dutch navy, reported in Kleijnen (1995). That study applies a number of simple statistical techniques, which were novel for the simulation modelers and their clients.

In the remainder of this short personal statement I will limit myself to those facets for which I have some expertise. That expertise is limited to *statistical* aspects of VV&A.

I claim that there is an *abyss* between validation practice and statistical theory! A challenge is to bridge that abyss. A start is needed: let us begin with the validation of relatively simple but practical simulations, *and report on their results*. A recent example is a case study by Halachmi et al. (2000) on the validation of a simulation model for a cow-milking robot developed in the Netherlands. This case study illustrates the many statistical problems arising when trying to validate a simulation model that is to be used in practice.

I further claim that *most simulationists lack a sound statistical training*. Many simulationists have good modeling and programming skills. Fortunately, modern simulation software simplifies the programming effort, including verification (debugging); see Swain (1999a)'s fourth survey on simulation software. Unfortunately, mastering the basic modules of such modern software still takes many hours of the students' time (this claim is based on my experience with teaching Arena - after many years of Pascal - to undergraduate students in Operations Research, using Kelton, Sadowski, and Sadowski 1998).

But, suppose the model has finally been programmed (I do not discuss the stages that proceed this programming, that is, I skip collecting data from the real system, etc.). Then the animation is watched for a little while. *All that effort may be a waste if the resulting simulation model is not validated*. The simulation's conclusions - to be implemented in the next stage - might as well have been based on throwing a coin - apart from the political gain that might be realized when management or the government can 'sell' its decision because 'the computer showed so'.

At WSC '99, I discussed which statistical techniques can be used to validate simulation models, depending on which *real-life data* are available, namely (i) no data, (ii) only output data, and (iii) both input and output data. Of course, as the data improve from (i) to (iii), the power of these statistical techniques increases. Simulationists should be aware of these techniques, which include Student's t-statistic, linear regression analysis, and basic design of experiments (DOE).

However, next these simulationists should be warned that in practice the *assumptions* of these statistical techniques might not hold! (That fact should not be interpreted as 'forget about statistics': first we should learn to walk, before we try to run.) So, we should pay much more attention to tests for checking whether the simulated and real data are indeed normal, independent, identically distributed (NIID).

If these assumptions do not hold, then the simulationists may apply either non-parametric techniques or bootstrapping. An excellent textbook on *distribution-free* techniques is Conover (1980). The *bootstrap* is a simple form of simulation that allows distribution-free, data-driven statistical analysis; see Efron and Tibshirani (1993). Indeed, bootstrapping for validation of simulation models is applied in a WSC '00 paper, namely Kleijnen, Cheng, and Bettonvil (2000).

For all these analyses we need *user-friendly statistical software*, possibly combined with expert systems and artificial intelligence. Also see Swain (1999b).

Concerning verification, I point out that a basic module of any simulation program is the *pseudorandom number generator* (PNG). Typically, however, simulation software is developed by computer experts who are unaware of PNG pitfalls. For example, modern hardware allows simulationists to make longer runs, so a necessary (but certainly not sufficient) requirement is very long PNG cycles.

Concerning PNGs and software, my experience is limited to two simulation software products. One supplier claims that PNGs are no problem anymore, so they do not deserve any attention. The other does provide some facilities, but the basic PNG is obsolete, and the facilities do not work properly (common and antithetic seeds do not work). For solutions I refer to L'Ecuyer (1999).

3.1 References

Balci, O. 1999. A methodology for accreditation of modeling and simulation applications. Technical Report, Department of Computer Science, Virginia Tech, Blacksburg, VA.

Barcelo, J. 2000. Putting the rush back in rush hour. *OR/MS Today*, 27(2): 36-40.

Conover, W.J. 1980. *Practical non-parametric statistics,* second edition. Wiley, New York.

Efron, B., and R.J. Tibshirani. 1993. *Introduction to the bootstrap*. Chapman & Hall, London.

Halachmi, I., A. Dzidic, J.H.M. Metz, L. Speelman, A.A. Dijkhuizen, and J.P.C. Kleijnen. 2000. Validation of a simulation model for robotic milking barn design. Working Paper, submitted for publication.

Kelton, W.D., R.P. Sadowski, and D.A. Sadowski. 1998. *Simulation with Arena*. WCB/Mc Graw-Hill, Boston.

Kleijnen, J.P.C. 1995. Case study: statistical validation of simulation models. *European Journal of Operational Research*, 87(1): 21-34.

Kleijnen J.P.C. 1999. Validation of models: statistical techniques and data availability. In *Proceedings of the 1999 Winter Simulation Conference*, eds. P.A. Farrington, H.B. Nembhard, D.T. Sturrock, and G.W. Evans, 647-654.

Kleijnen, J.P.C., B. Bettonvil, and W. van Groenendaal. 1998. Validation of trace-driven simulation models: a novel regression test. *Management Science*, 44 (6): 812-819.

Kleijnen, J.P.C., R.C.H. Cheng, and B. Bettonvil. 2000. Validation of trace-driven simulation models: more on bootstrap tests. In *Proceedings of the 2000 Winter Simulation Conference,* eds. J.A. Joines, R. Barton, P. Fishwick, and K. Kang.

L'Ecuyer, P. 1999. Good parameters and implementations for combined multiple recursive random number generators. *Operations Research*, 47(1): 159-164.

Naylor, T.H., J.L. Balintfy, D.S. Burdick, and K. Chu 1966. *Computer simulation techniques*. Wiley, New York.

Swain, J.J. 1999a. Imagining new worlds. *OR/MS Today*, 26(1): 38-51.

Swain, J.J. 1999b. Desktop statistics software: serious tools for decision-making. *OR/MS Today*, 26(5): 50-60.

4 VIEW OF AVERILL M. LAW

I have been interested in *practical* techniques for validating discrete-event simulation models since 1977, in the context of performing numerous real-world simulation studies, developing materials for simulation short courses, and doing funded research for the Office of Naval Research and the Defense Modeling and Simulation Office. In the past twenty years, I have seen *very few* new techniques developed that can actually be used to "validate" a wide variety of simulation models. Validation is inherently difficult because the systems under study are either proposed modifications of an existing system or represent completely new systems. Thus, it is difficult, if not impossible, to obtain performance measures from the actual systems of interest to use for validation purposes. In this sense, I do not see model validation as a particularly fertile area for future simulation research.

The most definitive technique for validating a simulation model of a proposed modification of an existing system is to simulate first the current system and to compare the model performance measures with the corresponding system measures. In the case of a manufacturing system, the performance measure of interest might be the average time in system of a part. Performing this comparison using a formal statistical technique such as a confidence interval is typically impossible since the available output data are not independent and identically distributed (IID), which is a requirement of classical statistical procedures. In the manufacturing example, neither times in system from a single simulation run nor times in system from the actual existing system are IID. One possible way of circumventing this problem is to collect several independent sets of data from the actual system and to compute a performance measure from each data set – the resulting performance measures are IID provided that the different data sets are collected under similar conditions (see Law and Kelton (2000, Chapter 5) for a more detailed discussion). However, the problem with applying this idea in practice is that one is usually fortunate to have even one good set of data from the existing system. As a matter of fact, I have only seen one simulation project (either my own or published by someone else) where there was more than one set of system data available and where this idea was actually applied. Thus, in practice the comparison of the model and system performance measures is typically done in an informal manner.

I therefore believe that it would be desirable for someone to develop a general-purpose, confidence-interval procedure (rather than a hypothesis test) based on one set of real-world data that could be used for validation purposes.

4.1 Reference

Law, A.M., and W.D. Kelton. 2000. *Simulation Modeling and Analysis,* third edition. McGraw-Hill, New York.

5 VIEW OF IAN MCGREGOR

Additional research in verification, validation and accreditation is not needed. What is needed is to put VV&A into practice. The two ingredients often missing in simulation projects are (a) awareness on the part of the client of the importance of a close involvement in the VV&A process throughout the project and (b) awareness of simulation practitioners of the following ideas based on Balci (1998), Sargent (1999), and Banks, et al. (2000):

1. VV&A is not a discrete step in the simulation process. It needs to be applied continuously from the formulation of the problem to the implementation of the study findings. There is no such thing as a totally validated and verified model. Validation and verification of models is never complete. Even textbook models with 50 lines of logic often have errors; increase that by a factor of 100 to get a realistic sized model of a medium manufacturing and materials handling system to be further persuaded that total VV&A is impossible.
2. The cost of VV&A increases exponentially with the level of verification. To obtain a model that is 50% verified and validated may cost $5,000. To get 80% of the way may cost $25,000, 90% of the way may cost $50,000, and so on. Decision makers have to decide the point at which they will accept the model results.
3. More planning for VV&A needs to be done prior to launching a simulation study. Part of this planning is how much of the total resources should be expended for VV&A and how VV&A will be accomplished. This is analogous to a test plan in software engineering.
4. VV&A should constitute from 20% to 30% of the resources expended for a simulation study. The actual modeling constitutes 30% to 40%, so VV&A should be a large component of the investigation.
5. The model developer may not be the best person to ascertain VV&A. Model developers are unavoidably biased, looking for the good and overlooking the bad parts of their models. Adding further members to the team for this step is likely to increase the price of the study, which is not always popular with the client.
6. There is no one best way to perform VV&A. Every model is different, with different circumstances. Even two models of the same system may have different VV&A procedures since the objectives of the studies might be entirely different.
7. Beware of the Type III error (solving the wrong model). This can be caused by lack of involvement with the decision makers or an inadequate list of assumptions. In any case, it is a major catastrophe when it occurs.
8. Statistical techniques such as t-tests are not easily used when it comes to VV&A. In order to use a t-

test of differences, for example, multiple sets of historical data have to be available, and these rarely exist.

9. Naylor and Finger (1967), many years ago, advocated the building of models with high face validity. If practitioners would just use a test of reasonability, VV&A would benefit greatly. Many times, simulation analysts fail 'to see the forests for the trees.'
10. Most simulation products provide animation support. Take advantage of it when verifying and validating a model.
11. The debugger, interactive run controller, or whatever else it is called in the simulation software that you use can provide great help in verifying a model.

In conclusion, what we need is more practice of VV&A, more involvement between the analyst and the client, and more awareness of the concepts of VV&A such as those presented above. We do not need additional research.

5.1 References

Balci, O. 1998. Verification, Validation, and Testing. In *Handbook of Simulation*, ed. J. Banks. John Wiley, New York.

Banks, J., J.S. Carson, B.L. Nelson, and D.M. Nicol. 2000. *Discrete-Event System Simulation*, 3rd ed. Prentice-Hall, Upper Saddle River, NJ.

Naylor, T.H., and J.M. Finger. 1967. Verification of Computer Simulation Models. *Management Science*, 14, 2, B92-B101.

Sargent, R.G. 1999. Validation and Verification of Simulation Models. In *Proceedings of the 1999 Winter Simulation*, eds., P.A. Farrington, H.B. Nembhard, D.T. Sturrock, and G.W. Evans, 39-48

6 VIEW OF ROBERT G. SARGENT

I believe there are several areas that are in need of VV&A research. These areas identify different directions that VV&A research can pursue.

One area is how should VV&A be handled with respect to the "size" and "type" of a simulation study. Consider the ranges that simulation studies cover: from small simulation models that have a few lines of simulation language code to very large-scale simulation models that have thousands of lines of general purpose computer language code, and from models of simple existing systems which can have experiments performed on them to models of large-scale systems which do not yet exist. Research is needed to determine with respect to the size and type of simulation study (i) which VV&A approach should be used, (ii) how should VV&A be managed, (iii) what type of software support system for VV&A is needed, etc.

A second area is the numerous VV&A issues in performing large-scale simulations that combine different simulation (sub) models and use different types of computer hardware such as in currently being done in HLA (Higher Level Architecture). A number of these VV&A issues need research. Consider, for example, how does one verify that the simulation clocks and event (message) times (timestamps) have the same representation (floating point, word size, etc.) and validate that events having time ties are handled properly.

A number of simulation professionals, including myself, believe that it is impossible to verify and validate large-scale simulation models to a reasonable confidence level. In addition, it is extremely costly to even attempt to obtain a reasonable confidence level in such models. Thus, I believe another area of research is to investigate how and when a set of smaller of simulation models should be used instead of one large-scale simulation model.

A fourth area for VV&A research is to develop a set of cost models to predict how much it will cost to conduct VV&A. Such models should consider the size and type of simulation models, the different approaches to VV&A, the amount of confidence that could be expected, etc. These cost models should be validated with real world data.

Another area for VV&A research is to develop new ways to convince sponsors and users of models that VV&A is required.

A sixth area is to develop fundamental new approaches of conducting VV&A.

Lastly, there is the area of developing new VV&A methods and techniques. These should have practical value.

7 VIEW OF SIMONE YOUNGBLOOD

In March 2000 the Defense Modeling and Simulation Office (DMSO) underwent a change in course, pointing toward a "new vector" with a newly focused mission to "Lead, Integrate, and Leverage M&S (Modeling and Simulation) for the Warfighter." Reorganized to support the "new vector", DMSO currently has two programs that have direct bearing on a discussion related to strategic directions in VV&A research. The first is the VV&A Program which serves as the focal point for Department of Defense (DoD) VV&A policy and guidance development. The second is the M&S Science and Technology (S&T) Initiatives Program which is charged with the difficult task of anticipating those science and technology innovations which can be leveraged to best serve future Warfighters. This paper focuses on the convergence of these two programs, namely the identification of S&T focal areas which would support more effective and efficient VV&A implementation which in turn would lead to more credible

M&S to support the warfighter. These VV&A S&T focal areas would serve as the new direction or "new vector" for VV&A.

In order to define any vector, one must understand the starting point, the point of origin. For DoD this starting point has been the definition and institutionalization of basic VV&A terminology, concepts, and technology. Policy and guidance documents currently in place provide a solid foundation for DoD VV&A activities, with policy describing the 'who' and the 'when' and guidance defining the 'what' and the 'how'. Working from this foundation, the DMSO VV&A Program has made initial inroads into addressing some of the technical challenges which are critical to effective and efficient VV&A implementation, including: clarification of the relationship of M&S and data V&V, the definition of the conceptual model, and the development of a fidelity framework. These technical challenges are considered "near" term challenges, not because they are easy to solve or because they can be solved in a relatively short time, but because a solution is required to be able address the next phase of technical challenges. The DMSO VV&A Program currently projects that the next phase of technical challenges include the following topical areas: specifications for reuse, substantive interoperability, and human behavior representation validation. These topical areas focus on three of DoD's "hot-buttons", namely reuse, interoperability, and human behavior representation (HBR).

7.1 Specification for Reuse

The concept of reuse within the DoD M&S community is predicated on the belief that a simulation can be used to support different applications and be used in ways not originally conceived of when the simulation was built. However, without documentation which identifies an M&S's capabilities, domain of applicability, and its underlying assumption, it becomes difficult, if not impossible, to assess whether or not a simulation is capable of meeting user requirements. The idea behind "Specification for Reuse" is to identify and formalize the core set of information necessary to perform an assessment regarding the capability of an M&S to credibly support a given application.

The near term goal of a conceptual model description plays a crucial role in defining a specification for reuse.

7.2 Substantive Interoperability

In any distributed simulation (e.g., HLA, DIS), there are two aspects of interoperability that must be addressed. The first labeled technical interoperability, is defined as the "capability of federates [simulations] to physically connect and exchange data (Dahmann 1999)." This is the aspect of interoperability which most people are familiar with and which the HLA framework addresses.

The second aspect of interoperability is referred to as substantive interoperability and it is focused on "fair fight" and representational issues. As Dr. Dahmann states in her SIW paper (Dahmann 1999) on interoperability challenges: "Resolving technical interoperability issues insures that the federation will run, but says nothing about the adequacy of the federation to accomplish its mission." Dr. Dahmann goes on to say that: "In essence, building a federation that incorporates representations appropriate to the needs of a the federation application is the heart of the VV&A problem." While High Level Architecture (HLA) technologies support simulation inter-communication, they do not yet achieve substantive interoperability. These essentially VV&A problems are presently tackled by engineering judgment, but as the level of federation complexity grows this approach quickly becomes less tenable. VV&A must mature to support substantive interoperability.

The near term goal of an established fidelity framework plays a crucial role in addressing substantive interoperability issues.

7.3 Human Behavior Representation Validation

One of the major thrusts in DoD today is the development of credible human behavior representations. Representations are needed at multiple levels including that of individual combatants and non-combatants, teams, platforms, military and non-military organizations, groups and crowds. The human element can be represented in simulation by real humans (e.g., trained controllers), humans supported by tools (semi-automated), or by models (automated).

Several key initiatives, including the DMSO HBR Program and the NATO Long Term Scientific Study on Human Behaviour Representation (LTSS SAS-017) have identified HBR validation as one of the arena's key challenges. Their Validation Roadmap includes the development of: a systematized best practices; informal methods and tools to support HBR validation; and formal methods and tools to support HBR validation. The VV&A community must work to support this validation roadmap.

The near term goal of an established fidelity framework plays a crucial role in addressing human behavior representation validation.

The challenges outlined in this paper have not simple solutions. They are, however, critical to the advancement of VV&A.

7.4 Reference

Dahmann, Judith, et al. 1999. HLA and Beyond: Interoperability Challenges. *1999 Fall Simulation Interoperability Workshop*, Orlando, FL.

8 SUMMARY

Apparently there are different VV&A needs in the different application domains; at least as expressed in the views of the panelists. In the industrial domain, apparently the two major VV&A issues are obtaining support in simulation studies for VV&A and having analysts who have sufficient knowledge of VV&A. In the military domain, there is a variety of VV&A issues needing research; in particular, for large-scale simulations. Academic people see the need for VV&A research in a broad sense. Several VV&A areas, topics, and issues needing research were identified.

ACKNOWLEDGMENTS

The Chair of this panel thanks Osman Balci and Jerry Banks for suggestions of individuals to be panelists.

AUTHOR BIOGRAPHIES

ROBERT G. SARGENT is a Research Professor and Professor Emeritus at Syracuse University. He received his education at The University of Michigan. Dr. Sargent has served his profession in numerous ways and has been awarded the TIMS (now INFORMS) College on Simulation Distinguished Service Award for long standing exceptional service to the simulation community. His current research interests include the methodology areas of both modeling and discrete event simulation, model validation, and system performance evaluation. Professor Sargent has published extensively and is listed in *Who's Who in America*. His web and email addresses are `<www.cis.syr.edu/srg/rsargent/>` and `<rsargent@syr.edu>`.

PRISCILLA A. GLASOW is a Lead Simulation and Modeling Engineer with The MITRE Corporation, a federally-funded research and development center. She is one of the Department of Defense's (DoD) leading experts in Verification, Validation and Accreditation (VV&A) of models and simulations. Mrs. Glasow has served as a lead consultant to numerous DoD organizations, including the Defense Modeling and Simulation Office (DMSO), the Ballistic Missile Defense Organization (BMDO), the Joint National Test Facility (JNTF), and the Navy's Modeling and Simulation Office (NAVMSMO). Among the many programs that she has supported are DoD's flagship analytical and training simulations, Joint Warfare System (JWARS) and Joint Simulation System (JSIMS). Mrs. Glasow has authored numerous VV&A courses and technical papers, including a widely-read series on the relationship of VV&A to test and evaluation (T&E).

Mrs. Glasow began her work in VV&A while on active duty and upon retirement from the Navy, was specifically requested to establish DMSO's VV&A program. Under her leadership, the first DoD VV&A policy (DoD Instruction 5000.61) was issued. Mrs. Glasow also served as the Editor and co-author of the original DoD VV&A Recommended Practices Guide, which remains a seminal work in the practice of VV&A.

Mrs. Glasow is a Director of the Military Operations Research Society (MORS) and a Co-Chair of the MORS Senior Advisory Group for Modeling and Simulation. She is a contributing and active member of numerous other professional organizations including the Institute for Operations Research and the Management Sciences (INFORMS), the International Test and Evaluation Association (ITEA), and the Society for Computer Simulation (SCS). Her email address is `<pglasow @mitre.org>`.

JACK P.C. KLEIJNEN is a Professor of Simulation and Information Systems. His research concerns simulation, mathematical statistics, information systems, and logistics; this research resulted in six books and more than 160 articles. He has been a consultant for several organizations in the USA and Europe, and has served on many international editorial boards and scientific committees. He spent several years in the USA, at both universities and companies, and received a number of international fellowships and awards. More information is provided on his web page: `<http://center.kub.nl/staff/kleijnen>`. His email address is `<kleijnen@kub.nl>`.

AVERILL M. LAW is President of Averill M. Law & Associates, a company specializing in simulation consulting, training, and software. He has been a simulation consultant to numerous organizations including Andersen Consulting, Boeing, Defense Modeling and Simulation Office, Kimberly-Clark, M&M/Mars, 3M, Xerox, as well as the U.S. Air Force and Army.

He has presented more than 325 simulation short courses in 17 countries. Dr. Law has written or coauthored numerous papers and books on simulation, manufacturing, operations research, statistics, and communications, including the book *Simulation Modeling and Analysis* that is used by more than 70,000 people. He developed the ExpertFit distribution-fitting software and wrote a regular column on simulation for *Industrial Engineering* magazine.

Dr. Law has been a tenured faculty member at the University of Wisconsin and the University of Arizona. He has a Ph.D. in industrial engineering and operations research from the University of California at Berkeley.

His web and email addresses are `<www.averill-law.com/about.htm>` and `<averill@ix. Netcom.com>`.

IAN MCGREGOR has a BSc in Production Engineering from Kingston Polytechnic in England, a Diplome d'Ingenieur in Applied Computing from the Universite de

Technologie de Compiegne and an MSc in Computer Integrated Manufacturing from the Cranfield Institute of Technology. He worked in the spatial and discrete event simulation department of Saint Gobain in France for three years, using four simulation packages. He moved to Paris to consult, train, distribute and support a simulation system before starting and running a simulation consultancy for two years. He joined AutoSimulations in 1996 to assist with their international expansion, which he continues to do. Ian McGregor has lived and worked in the UK, France, Singapore, Japan and the USA. His email address is <ian_mcgregor@autosim.com>.

SIMONE YOUNGBLOOD is a member of the Senior Professional Staff at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). For the past three and a half years, Ms. Youngblood has served as the DoD VV&A focal point in her position as DMSO's VV&A Technical Director.

Leveraging an extensive background in simulation development, modification and application, Ms. Youngblood has been active in the VV&A community for the past nine years. She has supported various V&V efforts including the Army's Advanced Regional Exploratory System (ARES), the Navy's Naval Simulation System (NSS), the Marine Corps Emerald Flair Project, and the JWARS prototype. She is currently coordinating a revision to DoD's VV&A policy (DoD Instruction 5000.61) and has served as Editor and co-author of the web-based DoD VV&A Recommended Practices Guide, Year 2000 edition.

Ms. Youngblood is active in numerous organizations that focus on VV&A. From 1994 to 1997, she served as Chair of the DIS VV&A Sub-Group and was co-author and editor of the IEEE 1278.4 Recommended Practices Guide for Distributed Interactive Simulation - Verification, Validation, and Accreditation. From 1997 to the present, Ms. Youngblood has chaired the SIW VV&A Forum. Ms. Youngblood also is active in the Society for Computer Simulation and the Military Operations Research Society.

Ms. Youngblood has a BA in Mathematics and a BS and MS in Computer Science. Her email is <syoungblood@dmso.mil>.