THOUGHTS ON SCIENCE AND MILITARY SIMULATION

A Position Paper for the SimScience Workshop

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ABSTRACT

This article addresses the question "could there be a science of simulation?" The question is related to the question of the establishment of a unique profession for simulation. Arguments for and against a simulation profession are outlined, and conclude with ambivalence. The relationship between modeling and experimental design as art forms is briefly discussed. A few barriers to the practice science that arise from the arenas of politics and computing are also highlighted. The article concludes by identifying areas within the military simulation community where scientific methods would be of significant value. These areas include: simulation-based acquisition, battlefield modeling, architectures and interoperability, the interface between testing and evaluation (T&E) and modeling and simulation (M&S), and a more rigorous peer-review publication practice.

INTRODUCTION AND DISCLAIMER

This "position paper" has been developed for a workshop within which the relationship between simulation and science is to be examined. Whenever professional self-deprecation is called for—as it all-too-often is in my case—I sometimes appeal to a brilliant quote whose attribution I am unsure of: "*Any discipline that calls itself a science, is not one*." I am in possession of three degrees in Computer Science. So, while I would consider myself a modeling and simulation (M&S) professional, whether or not my discipline qualifies me to discuss the nature of *M&S as science* is clearly a judgment call.

Furthermore, while my graduate work in M&S could arguably be considered a *somewhat* scientific endeavor, my post-graduate career has been spent in service of the U. S. Federal Government—specifically the U. S. Department of Defense (DoD). Practicing science in a political arena is difficult … at best.

And further still, for the past several years, I have been serving in an M&S policy office for the Headquarters, Dept. of the Army. There isn't anything scientific about Powerpoint.

My dubious qualifications having been established, I will now unabasedly regale the intrepid reader with my thoughts on the nature of M&S as science.

ON SCIENCE

I will leave to other workshop attendees more learned in the history and philosophy of science than myself to establish the overall framework for the SimScience debate. I frankly much prefer Michael Crighton to Karl Popper. I am more-or-less aware that science evolved from a discipline referred to as "natural philosophy" dating at least to the ancient Greeks, and that a "scientific revolution" is widely recognized as taking place in the 1500s–1600s through the works of Galileo, Bacon, Newton, Descartes and so forth. I have read that the term *scientist* was coined by William Whewell in 1834 [1, p. 130]. I am aware that the nature and value of science itself is the subject of considerable debate—debate regarding the nature of inductive vs. deductive reasoning; debate on the value of hypotheses, experiment, and probabilistic inference. Each of the debates within the broader Philosophy of Science must be

manifest in any discussion of the science of simulation. However, these do not seem surmountable within the confines of this article (not to mention the confines of my own intellect).

For purposes of this position paper, I will regard science as a *rigorous, repeatable, process through which knowledge is attained*. Certainly, knowledge is gained through means other than scientific inquiry. However, many believe (as do I) that the structure of scientific method provides the most productive and reliable mechanism through which to attain knowledge—and hence the popular belief that *science is good!*

ON SCIENCE AND SIMULATION

One of the questions we are being asked to consider is "could there be a science of simulation?" That is, could (should) simulation be viewed as a science in the same way that biology, chemistry and physics are viewed as sciences? In the sections that follow, I'll begin to address that issue. But before engaging in that discussion, I would like to briefly examine a related question currently occupying the interest of the military simulation community: "is there (should there be) a *profession* for M&S?"

ON AN M&S PROFESSION

Does M&S constitute a "first class" profession, or is M&S more suitably treated as a technique that is applied *within* first-class professions?

Despite the fact that I consider myself an "M&S guy", I continue to vacillate on the idea of an "M&S profession." On the one hand, modeling is a notion/technique that pervades the human condition from playdough to Lincoln logs to leggos to Barbie dolls to WARSIM… We are all modelers. Mankind is certainly far too big a group to establish a profession around. But, on the other hand, I believe the kinds of things that go along with a profession (a shared body of knowledge, code of ethics, etc.) would be nice to have in the community I work in. For example, how many folks who show up at the biannual Simulation Interoperability Workshops know what "common random numbers" are? Not that everyone needs to be able to derive the statistical notion of variance from first principles (and not that I could either), but an "M&S guy" maybe ought know a little bit about what variance is, and why variance needs to be minimized in simulation output and how common random numbers are used to do this. So, from that perspective, the notion of an "M&S profession" appeals to me greatly.

And as for the "S" part of M&S, a survey would quickly illustrate that simulation is practiced within nearly every scientific and engineering discipline. So that would mean that all scientists and engineers are necessarily simulationists. Again, that would seem to be too big a group to effectively manage as a single profession. And if simulation is the business of all science and engineering, then inevitably it must be dealt with at the (necessarily smaller) "domain" level (e.g. biologists, chemists, economists, engineers, etc., will own the bodies of knowledge and the codes of ethics, and so forth, associated with the practice of simulation).

If simulation is somehow smaller than all of science and engineering, *then* what should happen? Well, isn't simulation *really* just a problem-solving technique—numerically approximating system state at time t in the absence of a closed-form solution for the system state at t? Do other problem-solving techniques have professional disciplines (sciences) attached? Probably some do, others don't. Is there a profession for linear programmers? Simulated annealers? Queueing theorists? Fuzzy mathematicians? Inductive provers? Differentiators? Integrators? Dividers and multipliers? Adders and subtractors? Or do these folks primarily view themselves as mathematicians, operations researchers, and so forth?

Like I said, I vacillate…

ON MODELING, ART AND SCIENCE

There are those—myself included—who will tell you that modeling is *inherently* an art form. Does this imply that modeling cannot be viewed as a scientific endeavor? While I believe the artistic nature of modeling does limit our ability to turn it into an engineering discipline, I do not believe modeling is disqualified from the realm of science. Constructing a model sufficient to satisfy a collection of modeling objectives is the same art as designing an experiment to test an hypothesis. There is clearly an artistic quality to the practice of simulation, but so, too, is there an artistic quality to the practice of all science.

ON SCIENCE, COMPUTING AND POLITICS

Science is largely about *repeatability*—especially experimental science. For knowledge to be accepted, the experiments leading to the acquisition of the knowledge must be repeatable. The scientific literature in biology, chemistry, medicine and so forth is filled with scholarly articles that describe the repetition of experiments originally reported by others. Computer science is notoriously unlike this. It is rare, if ever, that computer science journals con-

tain articles that repeat the work of others. Any discipline that calls itself a science, is not one.

Similarly, the halls of funding agencies in Washington D.C. echo with the mantra, "reduce redundant expenditures!" If something has been done once, there is considerable resistance to spending dollars to do it again.

The influence of computer science and politics has (at least) two ramifications that merit brief discussion.

The first impact, driven by computer science, is most manifest in the literature of the military training simulation community. While the military analytical simulation community is dominated by operations researchers, the military training simulation community seems to be dominated by computer scientists. Since repeatability isn't valued (or understood) by computer scientists, there are relatively few case studies (experiments) reported. Most articles on training systems describe the architectural and design aspects of these systems rather than their use. Computer scientists love to tell each other about data structures I suppose. The literature in the military analytic community is reflective of the broader operations research community and is much better in terms of describing the use of systems in such a way that the use could be repeated by others.

The second impact, driven by politics, is an attrition in the number of models available to support analysis and training. There is a belief that we have too many models in the government. "Why build a combat model if we already have a combat model?" And so there is currently a push toward driving the number of models down to a fairly small collection of major, so-called "authoritative" systems (e.g. OneSAF, WARSIM, JWARS) that solve all needs. While it may be true that poor management has resulted in a proliferation of highly redundant models, the current paradigm shift seems to be an over-correction—the balance between too many and not enough isn't clear. Models are, of course, opinions not facts. Having multiple opinions is arguably quite useful for systems analysis. The daily weather forecasts are the result of at least three separate models; why would one want to design a future force structure using only a single model? While fiscal reality dictates that we can only afford to build so many models, shouldn't we concern ourselves with building lots of inexpensive models rather than a few billion-dollar babies [2]?

ON MAKING MILITARY SIMULTION MORE SCIENTIFIC

In the paragraphs that follow, I suggest a few areas within which certain aspects of the scientific method might be employed for the betterment of the practice of simulation within the military community. (Oooh, how's that for a lofty sentence?)

Simulation Based Acquisition. There is a push in DoD generally, and within the Army under a program known as Simulation Modeling for Acquisition, Requirements and Training (SMART), to maximize the use of M&S across the product life-cycle. It is believed that the application of M&S makes "better, faster, cheaper" a reality. We believe this, mostly, because we look around at the commercial world and we see companies that employ simulation to improve their bottom lines. That's reasonable. These companies at least provide an existence proof that M&S is effective. But it starts to fall apart a little from there. Does the government measure the bottom line the same way that commercial entities do? No. Does the government use simulation in the same way than commercial entities do? Absolutely not. The folks that modeled distribution methodologies for Starbucks, for example, were probably not told that they *had* to use RTI NG and federate with a high fidelity, but partially-finished, latte server. They were probably allowed to do whatever they needed to do in order to optimize distribution. If government business practice isn't the same as commercial business practice, should the government, therefore, expect to reap the benefits of M&S in the same way commercial entities do? Probably not. The government needs understand the application of M&S within the governmental context, and needs to collect the data necessary to achieve this understanding. The government should not expect to see the same results from simulation that General Motors or Boeing sees, unless the government organizes and operates like General Motors or Boeing.

Science of battlefield modeling. This is a pretty big topic, and others within the workshop will address it better than I can. But the topic deserves at least a small mention here. Despite decades of investigation, our combat models are still not very robust. Part of the problem is that there is not enough data from combat, but even where data exists our models do not fit actual outcomes very well [3]. The notion of "PKs" itself has also been severely criticized [4]. Clearly, with most combat models, you tell the analyst the answer that you want, and the analyst will get the model to give you that answer—with wholly justifiable values for the input parameters. Has science failed us here? Or are we just victims of the circumstance of inadequate data and highly nonlinear systems dynamics?

Interoperability. This is an interesting topic that has preoccupied the military simulation community for the past couple of decades. It began sensibly enough, with SIMNET, but how we arrived at our current paradigm is perhaps worth examining. SIMNET was networked tank

simulators. Interoperating homogeneous simulators within a common "synthetic environment" is a perfectly reasonable thing to do. You want two tank drivers to learn how to work together in combat? Give them an environment to practice in. SIMNET evolved into the Distributed Interactive Simulation (DIS) protocol. DIS was developed to enable the interoperation of somewhat-less-than-homogeneous simulators within a common synthetic environment. Still, it is quite sensible to have trainees in tank simulators interact with trainees in helicopter simulators. Then a funny thing happened. It was called the Aggregate Level Simulation Protocol (ALSP). ALSP was designed to allow the interoperation of *wargames*. Specifically, to allow an Army wargame to interoperate with a Navy wargame, an Air Force wargame and so forth. The stated reasoning behind the development of ALSP was twofold: (1) combat is (will be) a joint endeavor of all the military Services, therefore we need environments that represent each Service's capabilities; and (2) only Service *x* can represent Service *x*'s capabilities. The first reason is valid. The second one is a little suspect. It is probably true that the Army best knows how to represent the Army capabilities, doctrine, tactics, and so forth. And likewise for the Navy, Air Force and Marines. But it doesn't necessarily follow that you need each Service to build its own model and then network these models together! Certainly, one could posit the development of a *single* model that had subject matter expertise (SME) from each of the Services as development guidance.

The High Level Architecture (HLA) sprung from DIS and ALSP, and the paradigm of interoperating everything has been adopted whole-heartedly by a populace that believes in its merits. Some very thoughtful work has been done on the dark side of this paradigm [5], but a true calculus of interoperability remains to be developed. To me, the idea of lashing together two perfectly good simulations is not unlike the idea of jumping out of a perfectly good airplane.

On the relationship between M&S and Test and Evaluation (T&E). Except perhaps for very trivial systems, system testing can never be exhaustive, nor provide us with 100% confidence in future system performance. Therefore, testing must confront the problem of *quantifying uncertainty and risk*. For example, limitations associated with the number of shots that are taken in a live fire test produce risk and uncertainty. These limitations may be overcome (somewhat) in simulation where hundreds of thousands of rounds may be fired, however risk in this context is incurred due to the fact that a model is an approximation of a system. Finding the optimal balance between hardware-based and M&S-based testing requires a delicate balance of cost, schedule and risk—with the understanding that neither cost nor schedule are infinite and risk can never be completely eliminated. Some work has been done in this area [6], but much more is warranted.

Rigor. DoD M&S types—particularly in the training arena—just don't practice rigor very well. In 1687 Isaac Newton stood on the shoulders of giants. Today we seem to have a hard time standing on each other's toes [7]. In the DoD M&S training arena it is not uncommon to see papers published that have no literature surveys. Even worse, proposals are submitted *and funded* with equally poorly-established bases in prior art. We don't avail ourselves of peer review. We should.

CONCLUSIONS

In this article, I have waxed-not-so-eloquently on the relationship between science and simulation. I have described a few areas within my community—the military simulation community—where the scientific method might be gainfully applied. I'm sure that there are few, if any, original ideas or insights offered here. I also couldn't say whether other communities suffer from the same ills. I suspect not, but I'll gladly let them speak for themselves.

ACKNOWLEGMENTS

The ideas presented in this paper have evolved through many lively debates, discussions and almost-but-not-quite-fisticuffs with Dell Lunceford.

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