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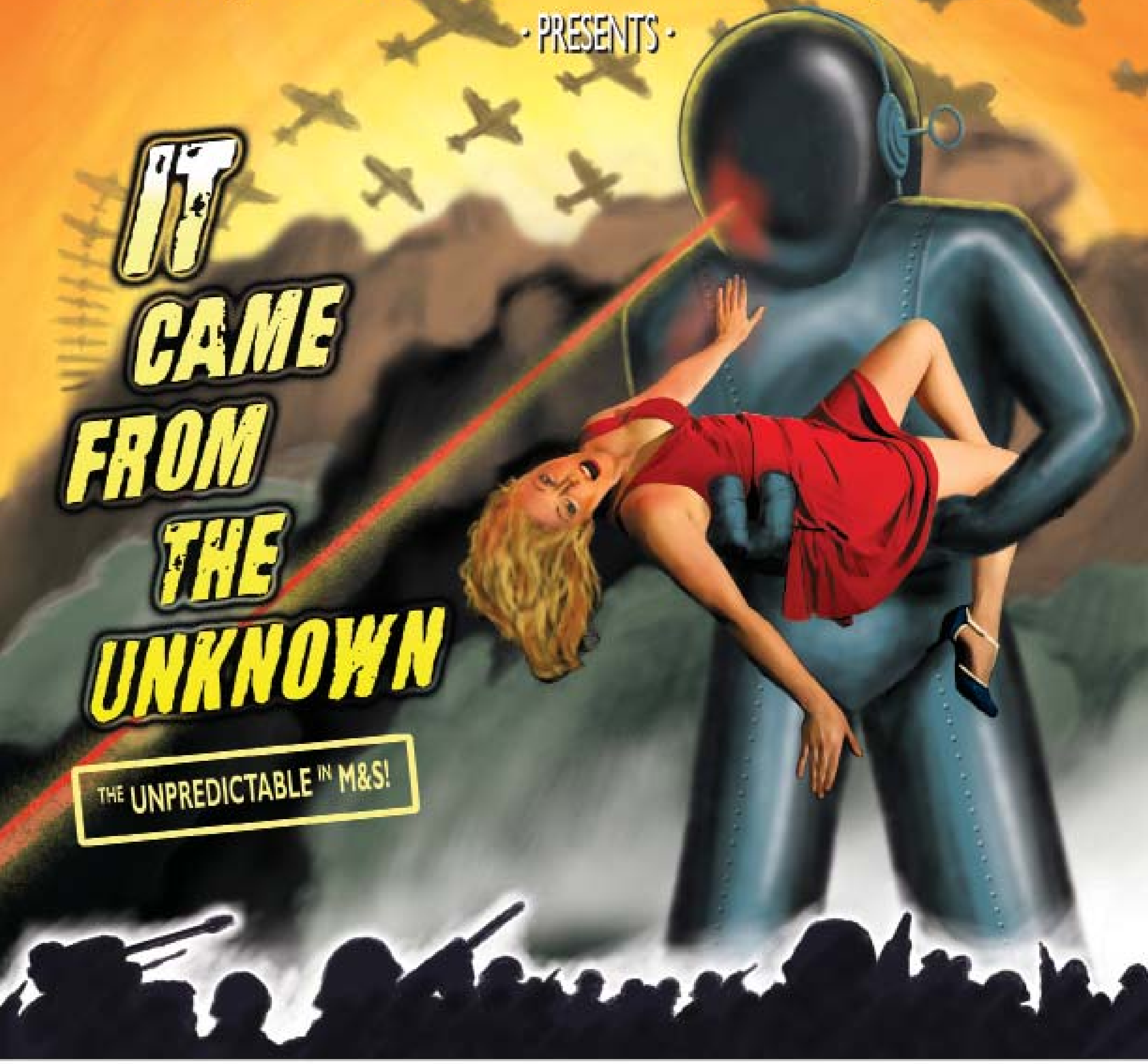

FEATURING **TEST AND EVALUATION** PAVING THE WAY FOR TESTING IN A JOINT ENVIRONMENT THE CAPABILITY TEST METHODOLOGY • **GAMES** JUST HOW SERIOUS ARE THEY? PHOTOGRAPHED IN TECHIECOLOR

AND INTRODUCING **MODELING HUMAN BEHAVIOR** WHAT THE NATIONAL RESEARCH COUNCIL SAYS, WHAT MARINE ANALYSTS NEED TO CONSIDER • IN **CINE-MS-SCOPE** AND **COLOR**

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Director's Welcome

I would like to welcome Dr. Amy Henninger as the newest member of the MSIAC Journal editorial board. Her editorial *On Uncertainty...* is a perfect entré to the theme of this issue of the MSIAC Journal. - Dane Mullenix, MSIAC Director

On Uncertainty...

As we proceed down the path of the "Long War" we are facing a fundamentally different operational environment than we faced during the "Cold War". Where we used to have a defined enemy with known equipment, tactics, and behaviors operating in a military-centric environment, we now have emergent and adaptive threats, and civil, cultural and infrastructure elements operating in a media-centric environment. These elements are not well defined, or even understood. As a result, there is no single best method to encode and describe the behaviors and the results of stimuli. There are, instead and in some cases, a plethora of models that each describes some element of the whole. And, it is generally accepted and understood that these models carry with them many assumptions and uncertainties.

Uncertainty is something we have spent years trying to quantify, minimize and avoid in our tools and studies. But, in this "Long War", the existence of uncertainty in our modeling efforts is more apparent than ever, and as we move towards representing data-sparse phenomenan or phenomenan lacking well defined theoretical underpinnings, the defense community is forced to recognize that as we design our tools and studies "uncertainty trumps utility". That is, as uncertainty about some domain increases, the utility of a traditional consolidative representation of that domain decreases.

In the first article by Mr. Chris DiPetto, we see that traditional methodologies for developing and testing systems will fail to fully describe real joint capabilities. Advancements in evaluation methodologies are required to demonstrate that future systems will integrate seamlessly in complex battlespace environments. Thus, we must "test, as well as train, like we fight". In the second paper by Dr. Paul Roman and Mr. Doug Brown, we witness the application of a contemporary technology to an age old problem: How to turn a team of experts into an expert team. And, in the third paper by Mr. John Lawson, we consider a Marine analyst's perspective on the National Research Council's latest review of human behavior modeling research.

Clearly, we are on the verge of a paradigm shift that moves our community from traditional consolidative modeling methods into next-generation methods for representation and evaluation. This is the thread that runs through this issue of the MSIAC Journal: "It came from the unknown – the unpredictable in M&S"!

The good news is we are not alone! Other communities have recognized this challenge and are developing approaches to reduce uncertainty. The meteorological modeling community, faced with potentially dire consequences for inaccurate forecasts has developed improved methods for dealing with uncertainty. Similarly, the machine learning community, faced with the challenge of learning very large domain spaces, has also developed effective means for reducing uncertainty. We must do the same. I encourage you to explore the power of computing and computational modeling as a means of reducing uncertainty, like these communities have done. Only by accepting (instead of ignoring) the uncertainty in the operational world and by implementing methodologies that embrace the diversity of different approaches, will we be positioned to better serve our Warfighters and the people who support them.

Amy E. Henninger, Ph.D.,
Associate Director, M&SCO

Guest Editorial

Simulation pervades our daily lives as never before. Due to the continuous evolution of computational capabilities, the powers of multi-dimensional, time-driven simulation environments are exploding. I propose that by taking the following three steps, we can capitalize on all of this "technology" to fulfill the requirements and goals of our simulation-related endeavors.

Step One: As a developer, first ask what the user wants. The user is that unique person who should know best what is wanted from a simulation. However, the user does not always appreciate or understand the full capabilities of computer systems or tools at hand.

Step Two: Find a way to help the user describe what is needed and then to see how the software or simulation development system can help realize that need. This requires a robust conceptual modeling toolkit that creates visualizations of processes, entity behaviors and system interactions. Conceptual models form the foundation of agreement between the user and the developer. This step should employ a unified modeling language or graphical interface with a wealth of diagrams to depict the user's goals and objectives. Both parties will then adjust and build a final view of the simulation's concept on paper.

Step Three: Once the developer and user are comfortable with the way the system is shaping up, then it's time to choose and use a programming language or environment. The programmer can start from scratch or reuse components from existing simulations or runtime environments. But, I caution—step one and step two must be completed first.

Now that you have the basis for building a simulation in a high-tech environment, you're ready to read the rest of this issue of the MSIAC Journal. This issue provides insights into three diverse, yet interrelated, areas in modeling and simulation. Following the spectrum from test and evaluation of our future joint environments, to new gaming implementations, to soft modeling of abstract modern concepts, the papers cover a wide expanse of important M&S subjects.

First on the list is Mr. Chris DiPetto's explanation and review of how a Live, Virtual and Constructive Distributed Environment enabled joint mission event testing and evaluation for command and control systems, including the Army's Future Combat System. Dr. Paul Roman and Mr. Doug Brown from Canada articulate serious gaming concerns and issues that have intrigued many of us in the simulation industry for years. Finally, the idea of Irregular Warfare M&S as related to behavior modeling is part of John Lawson's premise that IW modeling is often harder than thought, but does not have to be too complex to succeed. In these globally turbulent times with the Quadrennial Defense Review upon us, this is even more relevant.

In summary, the MSIAC team is confident that as you immerse yourself in this set of thought-provoking articles, you will learn how simulation-based environments enable and enhance mission accomplishment.

George F. Stone, Ph.D
Senior Scientist for Modeling and Simulation
Alion Science and Technology

Test and Evaluation:

Paving the Way for Testing in a Joint Environment
The Capability Test Methodology

Test and Evaluation

Paving the Way for Testing in a Joint Environment

The Capability Test Methodology

Chris DiPetto

The very nature of modern warfare necessitates major changes to the way the Department of Defense tests and acquires systems and capabilities. Since most systems today are deployed in joint environments, the testing of a system by a single Service may not be adequate to demonstrate that the system meets the warfighter's needs. Future systems, which are expected to operate in a joint environment, should be tested in a realistic joint environment throughout the acquisition life cycle, starting with early experimentation and concept development through the developmental and operational test. The result is an optimally integrated system.

DoD needs to ensure that it is testing systems, systems of systems (SoS), and capabilities consistent with their intended use. In other words, we test, as well as train, like we fight. The warfighter should be confident the systems work as advertised, and the tester must be challenged to deliver the future joint capabilities needed by the warfighter.

A New Roadmap

Changes in testing and acquisition processes are under way to make this happen. DoD instructions acknowledge the need to test joint capabilities in the expected joint operational environment. The Joint Capabilities Integration and Development System (JCIDS) is applying capabilities-based approaches to transform the way the DoD defines requirements for new systems and capabilities by moving materiel developers and testers away from the Service-centric system requirements of the past and toward the necessary joint-centric capability development for future systems. In November 2004, in response to strategic planning guidance direction to provide new testing capabilities and institutionalize the evaluation of joint system effectiveness as part of new capabilities-based processes, then-Deputy Secretary of Defense Paul Wolfowitz approved the Testing in a Joint Environment Roadmap, developed by the DoD director of operational test and evaluation. The roadmap calls for actions that establish a framework for the life cycle evaluation of systems and SoS in a joint operational environment beginning with the JCIDS process. Implementation of the roadmap focuses on three elements—policy, infrastructure networks and middleware, and methods and processes—while recognizing the important role of the Services and agencies in the execution. The purpose of the roadmap is to coordinate and synchronize the sometimes disparate Service and agency testing efforts by capitalizing on existing Service test assets, forming an approach to joint testing that will ensure systems and capabilities function as intended when integrated into the joint mission environment.

As individual platforms become part of a complex, networked SoS that must work effectively in a joint battlespace, effective test and evaluation is becoming more difficult. In the future, programs expected to operate in a joint environment should demonstrate their joint capability early and throughout their developmental cycles, regardless of the program's acquisition category. The objective of the roadmap is to address these challenges and define changes that will position test capabilities to fully support adequate test and evaluation of warfighting capabilities developed under DoD's capabilities-based processes in the appropriate joint mission environment.

The joint mission environment provides the operational context in which the capability being developed must perform. Important aspects of this operational context include joint mission, task, threat condition, environmental condition, and system or SoS descriptions of capabilities supporting the joint mission. The joint mission environment is realized when all relevant aspects of the joint operational context are adequately represented in an environment ready for a test that may be live, virtual, and/ or constructive and distributed in nature.

The Test Resource Management Center, established as a field activity reporting to the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, is chartered to be the steward of DoD test and evaluation infrastructure. In that capacity TRMC is responsible for the Joint Mission Environment Test Capability Program to help establish a DoD-wide live, virtual, constructive distributed environment (LVC-DE). To date, JMETC has laid the groundwork for an enterprise-level solution to testing infrastructure and has enabled that infrastructure to be assembled more quickly than in the past. Even with an effective infrastructure in place, there is also a need for policy changes and new methods and processes to make valid testing in a joint mission environment a reality.

The Methods and Processes

Traditional methodologies for developing and testing military systems expected to operate in a joint environment—particularly verifying specification compliance for individual systems and testing within a single Service environment—will fail to fully describe real joint capabilities. As DoD moves away from traditional single-system approaches to new joint capability-based approaches, the department must demonstrate that its future weapons integrate seamlessly into SoS and capabilities in complex battlespace environments to produce coordinated and focused effects. In addition, doctrine, organization, training, leadership, personnel, and facility aspects of these new capabilities along with materiel needs must be addressed early in the development process. DoD's long-term strategy calls for evaluations of joint systems effectiveness throughout all phases of a capability's development and deployment. As I mentioned before, we want to be able to test as we fight.

The challenge of testing in a joint mission environment begins early in the system acquisition life cycle; and it is daunting considering the number of systems, network combinations and interactions, environmental conditions, and non-materiel aspects that must be addressed for a realistic test. How much testing and data are sufficient? Must every possible combination of environmental conditions, modes of operation, systems, and entities within the joint mission environment be exercised? Replicating a realistic joint environment will be very challenging because the ability to assemble all required assets at a single test location will be nearly impossible because of scheduling constraints and resource availability. How much of this environment needs to be available for developmental testing and how much is required for operational testing? How can a realistic joint environment be constructed to enable it to meet both developmental and operational test objectives? What kinds of tests can be done during developmental testing to reduce the risk of uncovering new system deficiencies during operational testing?

To address some of these challenges as part of the larger roadmap effort, the director of operational test and evaluation chartered the Joint Test and Evaluation Methodology project in 2006. Specifically, JTEM was directed to develop, test, and evaluate methods and processes for defining and using an LVC-DE joint test environment to evaluate system performance and joint mission effectiveness.

JTEM has developed the capability test methodology, which is a collection of recommended best practices for designing a test of a system or SoS in a complex joint environment. The CTM provides a rational process that guides the program manager and test manager through the test planning process to tailor and optimize a test to demonstrate system performance within a joint context as well as system contribution to joint capabilities. It is a foundation for a series of guides, handbooks, and training courses that will ultimately be delivered to test organizations and acquisition PMs. The CTM is intended to:

- Address testing of systems, SoS, and capabilities, be they Service or joint
- Augment existing DoD and Service test processes 11 Defense AT&L: September-October 2008
- Align test and evaluation aspects and information across multiple DoD processes, namely Analytic Agenda, JCIDS, DoD Architecture Framework, and the Defense Acquisition System
- Provide recommended best practices for a consistent approach to describing, building, and using an appropriate representation of a particular joint mission environment across the acquisition life cycle
- Reflect current acquisition policies and instructions, and eventually be incorporated into Defense Acquisition University PM and test and evaluation courses.

The CTM is designed to augment, not replace, existing test methods and processes, taking into account the unique aspects of testing joint, networked systems in an LVC-DE. As such, the CTM closely parallels existing test processes used within DoD. The CTM consists of six steps and 14 processes, which are briefly described in the following paragraphs.

The CTM Steps

Step 0 defines the test evaluation strategy. The key process in this step is describing the Joint Operational Context for Test used to define the specific elements that make up the LVC-DE. The Joint Operational Context for Test includes a detailed description of the system under test, supporting systems, the expected operating environment, threat forces, and key system interactions and information exchanges required to complete a particular task or mission. In step 1, the PM creates a program introduction document, which outlines the details of a particular test or set of tests, communicating requirements to a test range. The test range then uses that document to produce a statement of capability, which is the starting point for determining what resources will be used to conduct the test and what data will be collected. Step 2 produces distributed test plans that are compilations of current individual test plans, with the addition of distributed and joint elements. During this test planning phase, early test concepts are developed into more detailed test plans. Test planning processes include test trial/vignette selection, refining the live, virtual, constructive distributed test environment required and synthesizing these activities into a test plan.

During CTM steps 3, 4, and 5, joint mission environments are assembled and used to support multiple test plans. Step 3 is concerned with technical systems engineering activities for automatic distributed LVC-DE implementation. These processes include the design of distributed configurations, the assembly of distributed components, and the integration of components into a distributed test range that meets customer requirements. In CTM step 4, distributed tests are conducted according to local procedures and data are collected. This phase produces test data for customers and reusable information for future joint mission environments. Though joint mission environments are assembled to support multiple customers, tests are not required to run concurrently. Sometimes individual customers may separately schedule only those parts of the joint mission environment they need to meet their own objectives for testing in a joint environment. Other times, multiple customers may share a joint mission environment at the same time for convenience or other reasons. In step 5, data sets are processed, analyzed, and evaluated (including evaluations of joint mission effectiveness and contributions of individual systems to joint missions).

Supporting Measures Framework

In addition to the CTM, JTEM has developed a supporting measures framework that establishes appropriate measures to support the evaluation of a system or SoS within a capabilities context. This framework is based on the JCIDS definition of a capability: "The ability to achieve a desired effect under specified standards and conditions through a combination of ways and means to perform a set of tasks." Measures of effectiveness are established at the mission level and based on combatant commander-desired joint mission effects. The joint mission effects are documented through a compilation of products that make up the Analytic Agenda, which is a DoD-wide framework for analyzing force structure requirements and other analytic studies. The products used to document desired effects include the defense planning scenarios, which are a series of scenarios that describe the range of military operations for which combatant commanders must be prepared, along with the operating forces and threats described in the multi-Service force deployment database and the current year and future year analytical baselines. The desired effects must be achieved under specified standards and conditions using systems; SoS; and the supporting doctrine, organization, training, leadership, personnel, and facility aspects, which make up the combinations of ways and means.

The systems and SoS have various performance attributes associated with them (e.g., launch range of an aircraft or time to disseminate information to the battlefield from a higher echelon headquarters), and they are ultimately are used to perform a set of joint tasks that achieve the joint mission desired effects. In the measures framework, measures of performance are used to describe the overall performance desired for each particular task. The joint tasks are described through the Universal Joint Task List and the

Joint Mission Essential Task List, along with the specified standards and conditions. The Universal Joint Task List and the Joint Mission Essential Task List also have corresponding Service task lists that support them. Although mission measures of effectiveness will be difficult to capture directly during tests in a joint environment, the task-level measures of performance and the system and SoS attributes can be readily measured. Analysis and combat modeling can then be used to determine overall measures of effectiveness for the joint mission desired effects.

Testing in a Realistic Environment

The CTM is addressing the ways and means for designing and executing tests of complex, networked SoS in a realistic joint mission environment through its newly developed and enhanced methods and processes. During their 2007 test event, JTEM demonstrated application of the CTM to a notional set of network-enabled air- and ground-launched weapon systems while employed in a joint mission environment supporting a joint fire support task. This test showed the potential that can be realized from testing networked SoS in a realistic operational environment. However, it also revealed many challenges, which fall into the categories of:

- Agreed-to measures of performance and effectiveness across multiple joint missions
- Persistence of the test environment used for testing
- Analysis and data management techniques to deal with the increasing complexity of planning tests and evaluating the results of tests in net-centric systems.

JTEM continues to address these issues. In this year's test event, the CTM's effectiveness and suitability for use in a complex joint test environment was again assessed using the Army's Combined Test Organization for Future Combat Systems' Joint Battlespace Dynamic Deconfliction event as a joint capability test event. This venue provided the opportunity to identify the challenges in integrating the end-to-end CTM into existing test activity, developing and maturing the LVC distributed prototype, investigating data-requirements issues, analyzing deficiencies in the joint mission environment representation requirements, and assessing the LVC distributed environment instantiation of the joint mission environment. Test event results are driving improvements to the CTM and will provide an opportunity to gain a better understanding of what it takes to fully realize a sufficient capability to test in a joint environment across DoD. In April 2009, JTEM will deliver a version of the CTM, along with guides, handbooks, and additional supporting documents, which will prepare PM and test organization customers to effectively test as the capabilities-based approach to acquisition requires.

Continuous Learning Available

Additional work has been accomplished to facilitate our future testing needs. The Defense Acquisition University and JTEM have partnered to develop a Testing in a Joint Environment continuous learning module, now available on the DAU Web site <http://clc.dau.mil/>. The module's goal is to familiarize DoD personnel with basic principles and practices related to testing in a joint environment. This three-hour credit course will enable capability managers, PMs, requirements managers, systems engineers, test and evaluation professionals, acquisition professionals, and warfighters to:

- Recognize the need for testing in a joint environment
- Describe the key DoD-level concepts that support testing in a joint environment
- Describe the generalized methodology for testing in a joint environment
- Define the structured approach for identifying measures that support testing in a joint environment
- Recognize the features of the joint mission environment.

The future of testing in a joint environment has many challenges and many exciting opportunities. Through the work of the Testing in a Joint Environment Roadmap and the efforts of all in the testing and acquisition communities, the challenges will be met and the opportunities will be exploited. This collective effort will enable us to test like we fight and deliver the future joint capabilities needed by the warfighter.

About the Author

Mr. DiPetto is the deputy director for developmental test and evaluation in the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. He has more than 28 years of experience in DoD and is Level III certified in T&E. He is a graduate of the U.S. Navy Test Pilot School and the Defense Systems Management College's Program Management Course, and is a 1994 Harvard Kennedy School of Government Senior Executive Fellow.

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Games- Just How Serious AreThey?

Games – Just How Serious Are They?

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Abstract

As military forces around the world begin to adopt gaming technology as an apparently cost effective and robust means for military tactical training it seems appropriate to consider how well suited they are for this task. This paper uses an evidence based approach to illustrate how American, British, Canadian and Australian forces are applying serious game (SG) technology to meet a variety of training needs. In particular, the paper uses these specific examples to address three questions: What tactical training requirements are serious games best suited to meeting? How effective and efficient are they at meeting those requirements? What are the technological limits associated with their use?

In answering these questions, the paper concludes that SGs are providing a cost-effective means to provide experience-based learning with emphasis on cognitive and increasingly affective training domains. War fighters will not develop the expert psycho-motor skills they need to effectively employ their weapon systems using game-based training. However, once the team of experts in various weapon systems is created, SG technology affords trainers the opportunity to turn them into an expert team capable of communicating well with the cognitive skills they need to effectively operate as teams. The examples demonstrate that this is true for infantry, armoured or combined arms training in open or urban terrain and holds for the very technologically demanding case of aviation training. To take full advantage of this capability, SGs need to be included as part of blended training solutions that take advantage of the strengths of the various types of training available with the SGs providing an experience-based learning alternative that has not been practically affordable since the end of the Cold War.

Introduction

Few would argue that the pedagogical advantages and impressive levels of resolution offered by the latest in video game technology make it clear that serious games (SG) have a role to play in military tactical training. Trainers close to the front lines have started adopting and adapting these tools to meet real and urgent training requirements.

In the Canadian Forces, for example, several training establishments are using their own budgets to acquire these surprisingly affordable software programs. There is no shortage of choice either as the video game industry comes to appreciate, what from their perspective might be perceived as a niche market, an opportunity to differentiate their products to meet the special needs of the military training market. Free trial licences and a willingness to accept feedback and make improvements are good business practices for these companies as they incorporate the needs of military users into products that, as a result of the increased realism, appeal to a much broader audience. One need look no further than the "Serious Games Showcase and Challenge" now in its third year at the I/ITSEC Conference to appreciate the broad scope of potential applications for military training. Furthermore, the 2007 I/ITSEC Special Event – "DoD Training – Impact of Gaming Technologies" was aimed at helping DoD determine what specific training needs could be filled with the application of game technology and gave serious games practitioners an opportunity to discuss how the industry might best meet these needs.

Urlocker and Smith (2007) chronicle the recent history of video game technology in the US Army and how it has grown to become a disruptive technology augmenting or replacing many of the less flexible and more expensive training technologies of the past. From the failed initial attempt with "Marine Doom" through the marketing success of "America's Army", the authors describe how and why video game technology has found its way into the main stream. This phenomenon is not limited to the military however, as explained by Smith (2007) who describes the five forces that are driving the adoption of game technology within multiple established industries of which the military is only one. Borrowing from the Five Forces Model popularized by Michael Porter (Porter, 1979) Smith uses an adaptation of this model to describe a traceable adoption pattern that can be easily mapped to the US Army experience with SGs (see Figure 1). It includes the niche market success (for recruiting) achieved through America's Army which provided the technology a new legitimacy or "foot in the door" that afforded innovators the opportunity to explore other options based upon an already legitimized technology. The next step in the adoption pattern, as described by Smith, is for applications to be certified for use by training authorities. A recent report on Coalition Simulation Interoperability in support of the American, British, Canadian and Australian (ABCA) armies' program highlighted that VBS 2® and OneSAF were the two simulation systems that all coalition armies were using or planning to use in the near future (Roman, et. al., 2007). This report argued for common tools as the best means to achieve simulation interoperability and proposed a SG (VBS 2®) and OneSAF as the current lead candidates for coalition simulation interoperability. The recommended practices in this report may lead to the last step in Smith's adoption pattern - mandatory standards. However, this may be several years away as the experimentation force (one of Smith's 5 forces) is likely to continue to influence the adoption pattern in the near future. Part of that experimentation is associated with determining the most effective ways to use game technology in support of military tactical training.

Pringle (2007) also supports the use of game technology in military training. He suggests that the extent to which SGs are expected to play an increasing role in training will depend on an ability to blend technologies in such a way that the training benefit is maximized. This implies a requirement to be able to measure the improvements achieved through the adoption of these technologies and a willingness to experiment with them. Unfortunately there are very few well defined or accepted standards for the specific measurement of the effectiveness of SGs and few military organizations conduct the required studies but rather seem to accept their use on faith.

One might speculate as to why this is the case, but there is considerable anecdotal evidence to suggest that commanders simply trust their intuition in terms of the effectiveness of these tools. For example, in preparation for an Afghanistan deployment, a Canadian Battle group employed the SG VBS® from Bohemia Interactive. As soon as the commander saw the value in the pilot implementation at the home station, he decided to integrate the tool into his Battle Group's high readiness training. It was by no means seen as a replacement to other training, but rather an enhancement that allowed the squads, sections and platoons to develop a cognitive understanding of the tactics techniques and procedures (TTPs) for various scenarios before executing them as part of live training. Difficult to practice scenarios such as convoy training were also greatly facilitated through the use of the game (Cote, 2007). The commander in this case clearly used his intuition to develop a blended training solution emphasizing the game for cognitive and difficult to practice skills combined with traditional live training to meet his specific needs.

The examples above illustrate that SGs are being used for some very serious purposes. There is a growing body of evidence to support the effectiveness of these tools, but there appears to be a lack of overall guidance on their strengths and current limitations.

In considering the question: "How Serious Are they?" This paper will attempt to address the following:

- What tactical training requirements are serious games best suited to meeting?
- How effective and efficient are they at meeting those requirements?
- What are the technological limits associated with their use?

What Tactical Training Requirements are Serious Games Best Suited to Meeting?

The current operational tempo within the Canadian Army has forced training policy and planning organizations to become increasingly outcome oriented. While there is a great deal of interest in all of the specific tools that are available, the pressures of limited resources (most importantly, time, personnel and money) have created a very strong desire for a systems view of both requirements

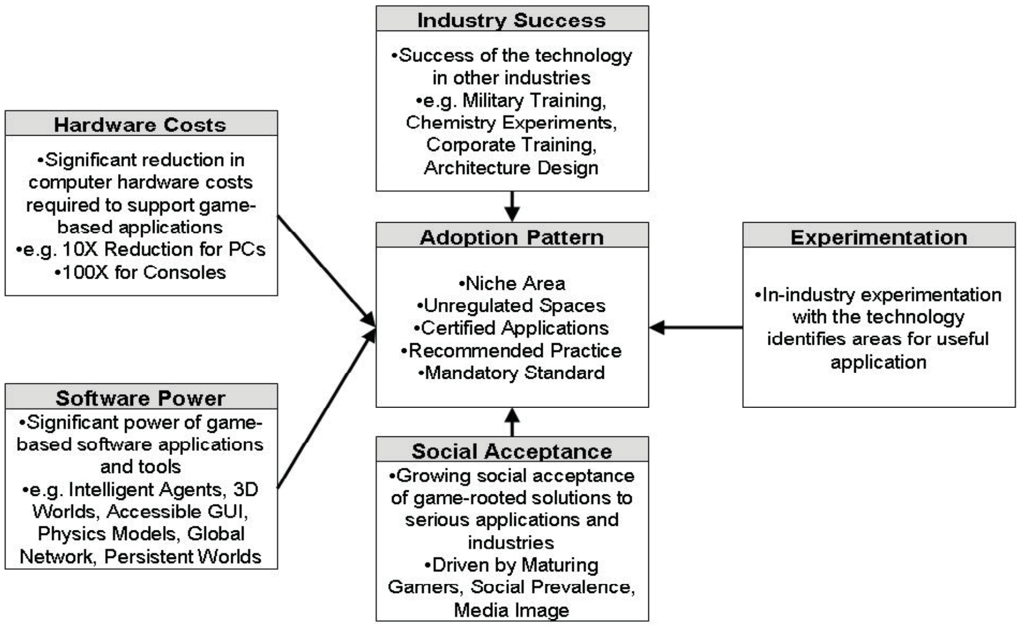

Figure 1: Five Forces behind the Adoption of Game Technologies by Diverse Industries (Smith, 2007)

and the means available to achieve them. The training needs framework (TNF), was created to provide this view (Roman and Bassarab, 2007). Figure 2 displays where SGs, are being used to support Canadian Army tactical training from individual (level 1) to company (level 5)

In the Canadian Army, the process of preparing forces for operational deployment is known as the "Road to High Readiness" (RHR). In many respects, the RHR is redesigned for each organization that goes through the process. It does, however, follow a relatively standard progression from individual skills to small team skills, combined arms teams and eventually full battle group tasks in the context of a brigade level operation. It does this by using the list of Battle Task Standards (Canadian equivalent of Mission Essential Task List) as the guide for the required capabilities. The culminating activity is a confirmation event conducted as live training at the Canadian Manoeuvre Training Centre (CMTC) in Wainwright, Alberta.

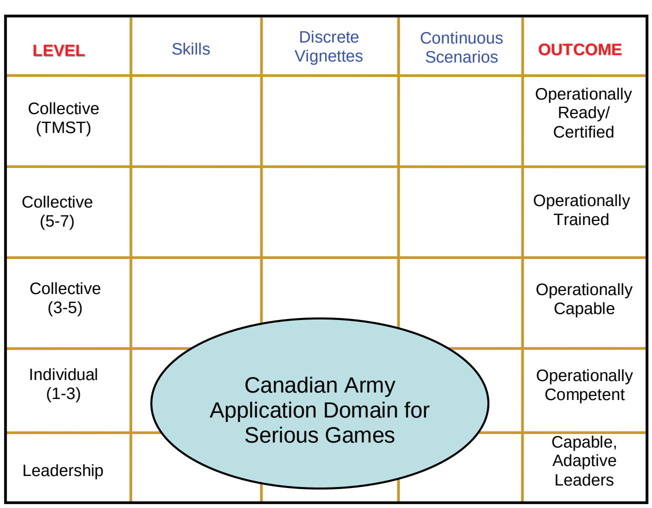

Figure 2: Application domain for SGs on the Training Needs Framework (Roman and Bassarab, 2007)

The RHR process uses experiential learning as its foundation. Menaker, Coleman, Collins and Murawski (2006) summarized the recent research on experiential learning as it relates to military training and advocated a structured learning cycle upon which to base the process. The authors stated that experiential learning events must:

- Engage the learner mentally.
- Emulate real-world environments. Real-world refers to the physical environment and the cognitive tasks.
- Allow the learner to experience effects of the decisions.

- Require the learner to reflect on outcomes of their actions. Build on established military practices of debriefs, lessons learned, and after action reviews.
- Revisit experiences with increasing levels of complexity to expand the learners' knowledge and skills by increasing the number of events, pace and emotional intensity.

The TNF supports this list of requirements. However, it goes further to provide a specific structure against which an appropriate learning cycle can be established. For example, the cycle builds from basic skills, such as small arms proficiency, to discrete vignettes in which the skills are practiced within various contexts. One specific example of this would be convoy operations. It then builds to continuous scenarios in which the learners receive increasing levels of cognitive loading where they must decide which actions are appropriate without knowing the overall context as would have been the case in the discrete vignette. Roman and Bassarab (2007) provide a specific example that illustrates the role of SGs as part of an overall training plan for rules of engagement training. From this example, the authors show that SGs provide an excellent fit with the requirements described above.

In addition to the Canadian Experience, British and American researchers are arriving at similar conclusions. In a series of studies funded by the UK Acquisition Research Organization, QinetiQ researchers demonstrated that training could be enhanced for dismounted infantry section and fire team TTPs. Anatolik (2005) went further to examine how much synthetic environment (SE) based training was appropriate in terms of a balance with live training. Although this study was limited to urban environments, users and trainers agreed that the video game based Dismounted Infantry Virtual Environment (DIVE), using the commercial game engine Half Life, was good for the following:

- Introducing, teaching and rehearsing new drills and TTPs.
- Showing the viewpoint of both sides, enemy and own forces.
- Representing the use and effects of current and future systems that either cannot be or are poorly represented in conventional training.
- Reviewing actions and events from all perspectives both during the event and in post game analysis.
- After Action Review (AAR). This was reported as a 'big win' and develops a feeling of inclusion in the training process for all participants.
- Developing new teams and fostering teamwork.

It was also reported that the representation of weapons and systems capabilities that cannot be represented in conventional urban training was extremely valuable. These included grenades (hand-thrown and under-slung), suppression, shooting through cover, and the effects of casualties.

Although the treatment of casualties is beyond the scope of this paper, it is notable that over the past decade, virtual reality (VR), which in this case includes game-based applications, is starting to make a significant impact on behavioral healthcare. The inaugural issue of the Journal of Cyber Therapy and Rehabilitation (JCTR) comprises seven papers that describe virtual reality applications for the treatments of psychological problems from schizophrenia to eating disorders (Weiderhold, 2008). Of particular interest from a military training standpoint is a paper written by Weiderhold & Weiderhold (2008) which is dedicated to VR applications in the treatment of post traumatic stress disorder (PTSD) and stress indoctrination training (SIT).

Australian researchers are also using VR integrated with SG technology to overcome aviation aircrewman training deficiencies. Carpenter (2008) describes an Australian Defence Force success that created the Aircrewman Virtual Reality Simulator (AVRS). This simulator provides a 360 degree field of view through a head mounted display that is stimulated by the SG VBS 2®. Carpenter explains that the AVRS project was created to address the unacceptable failure rates for aviation air crewman. The root cause was determined to be insufficient practice in appropriate scenarios and two simulation alternatives were evaluated to meet this need. They compared a high end dedicated Military Off-the-Shelf (MOTS) option, which was low risk but expensive, to a significantly higher risk development around VBS 2® that would cost considerably less. The project was approved in May, 2006 with all systems being delivered by November, 2007. Figure 3 shows the VBS 2®

based AVRS instructor module in the foreground with the trainee module in the background. The trainees get a full 360 degree VR view through the headsets.

Figure 3: Aircrewman Virtual Reality Simulator (Carpenter, 2008)

Carpenter reports improved performance with a substantially improved pass rate, higher standards and increased throughput as primary benefits for which the system was created. Additional benefits include the opportunity to practice in more realistic scenarios and in all types of weather. Students who require remedial training have the opportunity to do so and, as seems to be the case when cognitive skills are improved through game-based techniques, the live training was reported to have become both safer and more effective.

Effectiveness and Efficiency of Serious Games

The efficiency argument for serious games is relatively easy to make based upon cost savings. This is true of simulation in general, but even more so when using commercial off-the-shelf (COTS) software compared to relatively more expensive purpose built military simulations and simulators which need to be networked together for collective training. The implicit assumption with this argument, however, is that game-based training is being used to replace live training and this does not appear to be the case. Rather, SG training is increasingly being applied as part of blended training programs or as an enhancement to live training. What the SGs may be replacing, however, is instructor lead classroom learning and as a result, may well have a cost increase associated with their adoption and use. Many students can follow a single PowerPoint presentation on how to perform room clearing TTPs, however for a squad to practice and learn the cognitive skills in the SG will require hardware and software for each trainee. The distinction between following a presentation and learning in an SG is intentional because the SG enables an experience-based approach which is more effective than instructor lead PowerPoint presentations (Menaker et al., 2006). However, it clearly will cost more than classic classroom instruction which is very efficient, but arguably not very effective for training tactical skills. One might observe that the trend to increase experience-based learning through an increase in the use of SGs for tactical training is really a return to the training paradigms of the cold-war era which had considerably more emphasis on experience-based live field training. As part of the peace dividend, resulting from the end of the Cold War, there has been a significant decrease in training budgets and, as a result, considerably less "live" experience-based training. SGs provide a cost-effective alternative.

An excellent illustration of the relationship between efficiency and effectiveness of game based training is occurring at the Canadian Combat Training Centre (CTC). CTC comprises several specific schools and is currently experimenting with multiple SGs to meet dynamic training requirements. In one trial, the Armour School recently incorporated VBS® into the Troop Warrant Officer's course. Hill (2008) provided an assessment of the cost savings (efficiency) and performance improvements (effectiveness) associated with increasing the amount of game-based training in successive serials of the Troop Warrant Officers course conducted in 2007. In the first serial of the 6 week course, the trainees received 1 day of VBS® training and 5.5 weeks of live training in the field. Figure 4 shows a partial training layout including a tank crew (Leopard) and a surveillance crew (Coyote). Figure 5 is a photograph of one of the workstations. Based on the success with VBS® during the first serial, the training staff increased the VBS® portion to 2.5 weeks for the next serial and decreased live training to 3 weeks.

The costs of the second serial were reduced by approximately 33% due to the need for less fuel, food and

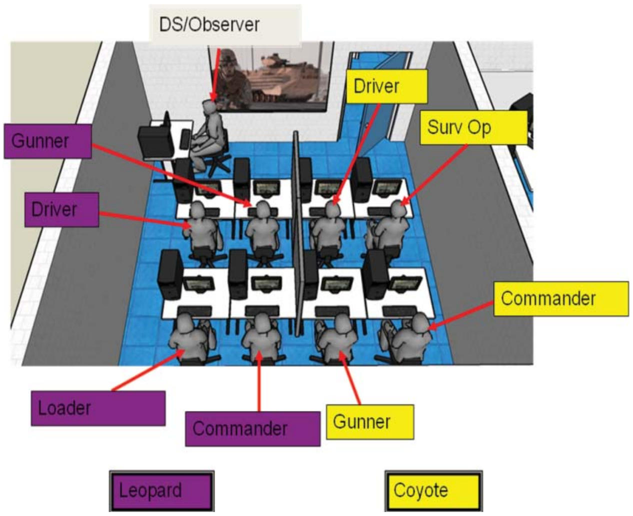

Figure 4: Partial Layout for Armoured Troop Warrant Officer Course (Hill 2008)

Figure 5: VBS 2® Workstations in the Armour School Battle Lab (Hill 2008)

field pay compared to the first serial. More significant, however, was the effect on performance (effectiveness). Hill measured performance based upon student success rates as defined by the proportion of students that pass this demanding course and the number of traces (live battle runs) needed to demonstrate proficiency. Table 1 presents the results from three consecutive serials of this course. Serial 0602 had no VBS® training, and can be considered a control group. All three serials had 18 students.

	Serial 0602 (No VBS®)	Serial 0701 (1 day VBS®)	Serial 0702 (2.5 weeks VBS®)
% pass on 1st trace	0	30%	67%
% pass by ½ of traces	61%	72%	100%
% pass by end of course	72%	83%	100%

Table 1: Performance Results with Increasing Amounts of Game-Based Training (Hill 2008)

As was the case with the Australian AVRS example described earlier, the game-based training resulted in a significant improvement during the field portion of the course. Serial 0702 was reported to be the first course with a 100% success rate which was achieved in all cases with only two live traces compared to the six traces required to achieve an 83% success in the previous serial. In his presentation of these results, Hill pointed out that there were many potential confounds associated with the improvements in performance including, for example, that there were different instructors for each course. Even so, the impressive improvement in performance has resulted in CTC considering the addition of SG content in the majority of the courses they deliver.

Despite this clear success, Hill and others emphasize that the cognitive training provided by game-based simulation does not replace the need for live training. They argue that the key to effective tactical training is to develop affordable, blended training solutions, as prescribed by Pringle (2007), which take advantage of the strengths and compensates for weaknesses of all of the training modes available.

A potential strength of game-based simulation lies in the area of behavioral or affective training. Whereas cognitive training addresses the mental skills required by trainees to develop knowledge, affective training deals more with their emotional state and ability perform under stress. Although there is a growing body of evidence supporting the effectiveness of game-based training for cognitive learning, there are relatively few studies exploring the affective learning aspects of game-based desktop simulators. A recently completed three year

Defence Advanced Research Projects Agency (DARPA) sponsored project employed physiological monitoring during simulation training and testing as a means to assess the degree of affective training provided by the game (Weiderhold and Weiderhold, 2006b). The overall objective of this research was to assess the effectiveness of using game-based laptop training with US armed forces personnel participating in simulation training prior to conducting live training. Specifically, the investigation examined the effectiveness of desktop training simulators to teach tactical and trauma care skills, to practice stress management and to improve performance during real-life combat situations. Nine hundred and seventy participants trained in a virtual combat scenario while their stress and arousal levels were monitored through noninvasive physiological means. A control group did not receive game-based training. All the participants were then tested in a live version of the same combat scenario to determine the effectiveness of the desktop immersive training. One subgroup of 210 United States Marine Corp (USMC) soldiers was observed during an 11-day training program. Ninety of the 210 subjects received desktop immersive training prior to live training and their performance was compared to the remaining 120 subjects who did not receive desktop training. Although the scenario in this example (proper identification and Breach techniques for a shoot house), was significantly different from the open terrain armoured traces described in Hill's presentation, the results were very similar. All personnel who had the opportunity to perform the scenarios in the game prior to the live training were assessed to be 100% accurate on all runs whereas the control group (no game-based rehearsal) was only 80% accurate 80% of the time. Furthermore, it was reported that the game-based rehearsals resulted in improved spatial awareness and the trainees completed their tasks more quickly with less need for communication as the team skills had been improved during the rehearsal. The desktop immersive trained personnel performed better at spatial awareness within the shoot house, moved more quickly entering the shoot house and required less communication than the control group, as each person was able to anticipate the other/team movements, in comparison to the control group that took an average of 6 seconds longer to perform the same tasks.

The study went into further details exploring more affective aspects for different groups of US personnel and came to the conclusion that affective and cognitive learning in desktop immersive trained groups helped them out perform in all tasks compared to those that had not received the training. Weiderhold and Weiderhold, (2008) explain this phenomenon as stress inoculation training (SIT) and argue that the benefits described above are due in part to the experience gained in the game and how that reduces the stress of performing in the live equivalent. This effect has been so pronounced, that the success demonstrated with these military examples has resulted in similar research efforts to provide SIT for medical personnel, the US Coast Guard and SWAT teams (Weiderhold and Weiderhold, 2008).

Another good practical reason to use simulation for training is if the actual equipment is 7000 miles away. In an excellent blended learning example, O'Bea and Beacham (2008) described how three types of simulation are being used to train US soldiers on route clearing operations prior to deployment in IRAQ. The motivation for this work was based upon the fact that the primary equipments used for clearing improvised explosive devices (IEDs) are being fielded directly into theatre without any systems in the US to support training. Operators do not see the actual equipment until they are deployed. To compensate for this gap, O'Bea and Beacham (2008) described how the combination of a "live" part-task trainer, a virtual reality system trainer and a game-based convoy trainer have been employed to get the Army Engineer Clearance Company ready for deployment. The part-task trainer is a hardware-based simulator with identical controls and performance characteristics to the mine clearing arm on the Buffalo that enables the operators to develop their psycho-motor skills as operators of the equipment. The Virtual Route Clearance Trainer (VRCT) is combined with classroom instruction to allow detachments to train as a team on the latest mine clearing TTPs and is reconfigurable to represent three different mine clearing systems. The training culminates with a game-based convoy scenario that employs DARWARS Ambush in which the clearance company detachments take up their role as part of a convoy allowing the full convoy team to train together in realistic scenarios that are tailored to meet specific threats expected to be encountered during operations. Figure 6 shows the DARWARS Ambush visual models of three of the clearance company's vehicles including the Buffalo with the articulated arm extended.

Figure 6: DARWARS Ambush Screenshot (US Army Photo, O'Bea and Beacham, 2008)

The mine clearing example and its use of a part-task trainer serves as a good reminder that Desktop game-based training is not well suited for the psycho-motor aspects. This is the one area in which certain negative learning aspects may come into play. To overcome this, low level mock ups and stations must be created that replicate the training that is desired and do not cause participants to achieve proficiency in an aspect of training that is not realistic. However, desktop game-based simulations can provide leaders and team members the ability to effectively practice the cognitive and decision making skills that they will need in real world situations. Knerr (2007) states that through focused, repetitive, deliberate practice with feedback based on performance, this is an ideal and effective method for training. What the examples above serve to illustrate is that this training should not replace live training, but rather SGs can make live training much more effective and efficient with soldiers meeting and even exceeding standards more quickly. The experience-based cognitive and affective learning provided by well conducted game-based training therefore, can make an overall blended approach both more effective and efficient.

What are the Technological Limits of Serious Games?

In examining the last question, two serials of a Canadian aviation exercise, Winged Warrior will be considered. Exercise Winged Warrior has traditionally been a live exercise intended to test tactical helicopter pilots in their role as aviation mission commanders during the planning end execution of complex missions. It serves as an excellent example to examine technical limits as tactical aviation is arguably the most difficult (military) case for an SG considering terrain models and graphics performance requirements. In addition to being relatively fast movers capable of covering large geographical areas, helicopters fly at low altitude demanding a high degree of visual detail. Aircraft flying fast and high can get by with a low-resolution picture draped over a low fidelity Digital Terrain Elevation Data (DTED) skin. This is not the case for aviation missions where pilots may often fly nap of the earth and would be especially limiting in exercises like Winged Warrior that include infantry units being supported by aviation. Winged Warrior also requires that the SG be federated with other simulations in order to meet a broad set of training objectives.

Typical aviation missions executed during the exercise included:

- Reconnaissance and surveillance
- Direction and control of fire
- Provision of fire support
- Combat airlift/tactical transport
- Logistical transport
- Communications support

Roman and Brown (2007) describe that the cost of the live exercise had become too great resulting in the creation of a game-based equivalent using a combination of the SG Steal Beasts® and the Joint Conflict and Tactical Simulation (JCATS) constructive simulation with the first serial occurring in 2006. Although the 2006 version of Winged Warrior was a tremendous success as the first SG application for command and staff training at the Directorate of Land Synthetic Environments, the sponsors of the 2007 version of the exercise wanted to overcome the following shortfalls from the previous year:

- Communications simulation limitations
- Lack of night operations
- No civilian personnel or vehicles

- No navigation instruments or electronic defence measures
- No door guns
- No control over weather
- No fast air
- Poor overview of entire battle-space

There was also a strong desire on the part of the Air Force to expand the scope of the exercise to include:

- Improving the in-air Command and Control presentation
- Expanding the training audience to include a Helicopter Squadron's Battle Staff
- The addition of distributed simulators.

Winged Warrior 07 was executed during the period 22-31 Oct 2007 at CFB Valcartier, just outside of Quebec City. Figure 7 shows how the Area Simulation Centre, housed in a former indoor rifle range, was configured for the training.

Winged Warrior was an unclassified exercise set in simulated Afghanistan using typical aviation missions on geo-specific terrain. See Figure 8 for an out the window view for the helicopter pilot in VBS 2®. Threats were typical and varied from the very simple to the extremely complex and included both civilian and non-combatants.

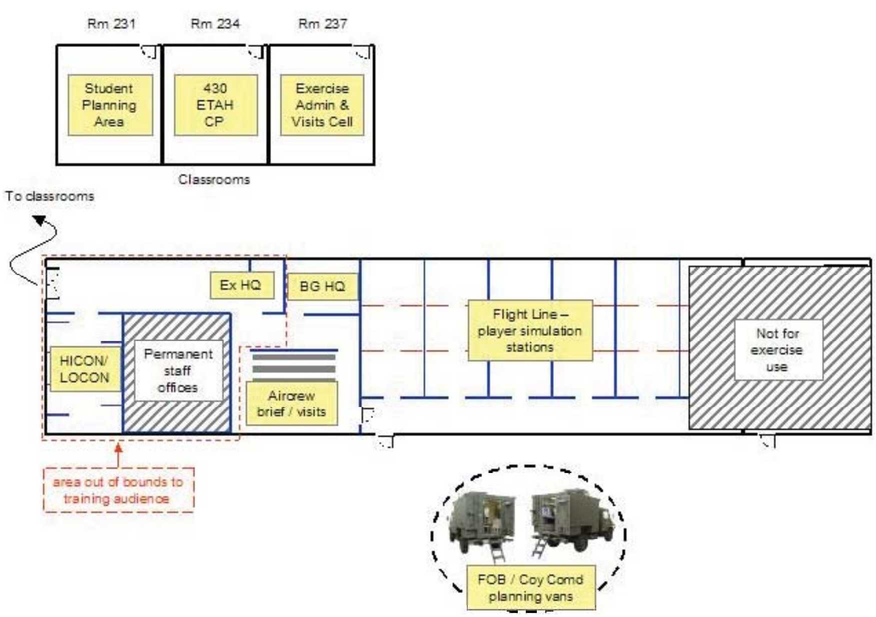

Figure 7: Exercise Winged Warrior 2007 Layout

To overcome the shortfalls from the 2006 version of the exercise, a simulation federation was formed with IEEE 1516 (HLA) forming the basis for the link to three geographically dispersed exercise locations (Valcartier, Ottawa and Kingston). IEEE 1278 (DIS) was used to link VBS 2® with JCATS. The following simulation components formed the federation:

- VBS 2®
- JCATS
- Raptor Simulator
- ASTi® simulated Radio

VBS 2® was selected as the primary visual simulation for the exercise. The majority of objects on the simulated battlefield were generated through VBS 2® with JCATS providing a larger background air picture and the Raptor simulator providing a single virtual platform for the exercise. Given the size of the terrain and the number of objects that had to be represented, the capability of VBS 2® was considerably stretched. Indeed it was well outside the nominal bounds of what this game engine was designed to be able to handle (ground based personnel and vehicles). This was the first military exercise that employed VBS 2® for a tactical aviation primary training audience. Despite these challenges, VBS 2® performed very well, meeting most of the pre-exercise training requirements. Game engines clearly have come a very long way. The ability to process and display a very large terrain file with a high degree of detail and lots of simulation entities speaks to a maturity of this technology. What was achieved on normal computer hardware using an adapted first-person shooter game for this exercise simply could not have been achieved two years ago.

The VBS 2® tool suite that supports terrain and scenario generation is due for a major upgrade in 2008. These tools were in their infancy during the lead up period to Winged Warrior. This complicated the construction of the terrain model for the exercise as this was the most complicated user created terrain model to date. Bohemia Interactive was extremely helpful in assisting in the use of these tools. Many of the observations made and lessons learned have been integrated in the new versions of these tools that will be sold as VBS 2 VTK® (Butcher, Johnson and Morrison, 2008) which will comprise both the game software, the VBS Tool Kit (VTK) to allow user modification and the software necessary to link VBS 2® with virtual or constructive simulations using HLA or DIS as appropriate.

The inclusion of a general-purpose constructive simulation proved to be a very useful component to the synthetic environment. From it, the overall air picture was easily generated and able to stimulate the secondary training audience from the helicopter squadron command post. This change from the 2006 version of the exercise was so successful that an even more advanced VBS 2® and JCATS synthetic environment was created. It is being used to support high readiness training of helicopter units potentially deploying to Afghanistan in 2008 and for future iterations of Winged Warrior.

Figure 8: Pilot view in VBS 2®

To date, the Winged Warrior series of exercises, arguably among the most demanding scenarios for SGs, have yet to be constrained by technical limitations. Looking forward, the hardware and software will only improve. Bigger terrain tiles, more terrain objects, better visual effects and more entities will be able to be displayed and natural market forces will result in game companies continuing to compete through improved capabilities which will in turn allow the generation of richer and richer visual environments and ultimately better and better training of this type.

Summary

This paper set out to address three questions regarding the use of serious game technology:

- What tactical training requirements are serious games best suited to meeting?
- How effective and efficient are they at meeting those requirements?
- What are the technical and pedagogical limits associated with there use?

Several specific examples have been provided that address the first question. It would be presumptuous, however, to assume that a list of specific requirements can be provided since the technology continues to evolve, new requirements continue to emerge and innovative researchers and trainers will continue to discover new uses over time. It is possible, however, to generalize from the examples provided to emphasize that SGs are providing a cost-effective means to provide experience-based learning with emphasis on cognitive and increasingly affective training domains. War fighters will not develop the expert psycho-motor skills they need to effectively employ their weapon systems using game-based training. However, once the team of experts in various weapon systems is created, SG technology affords trainers the opportunity to turn them into an expert team capable of communicating effectively with the cognitive skills they need to effectively operate as teams.

The body of evidence supporting the effectiveness of SG training solutions is starting to build and examples from the UK, Canada, the US and Australia have been provided. In all cases, the examples provided support the theoretical arguments that SG technology is most effective as part of a blended training solution that takes advantage of the strengths of the available training tools and processes. One consistent result is that using the SG prior to live training makes live training more effective and efficient. In the British, Canadian and USMC examples provided above, pass rates and performance conducted during live training were significantly improved when rehearsals were conducted using the SG compared to those that did not get the SG practice. In some cases, simulation may be the only training option as the trend to field the latest equipment directly into theatre results in a complete lack of training capability at the home station. Employing this equipment during collective training conducted in an SG as described above for the US Army Engineers Mine Clearance Company is arguably the only way to prepare troops to participate in combined arms teams using equipment they will not actually touch until they arrive in theatre.

In addressing the last question, the Winged Warrior experience clearly indicates that technology is not a limiting factor in terms of SG support to training exercises. Terrain database generation is improving rapidly, the games can be federated with other virtual and constructive simulations to meet a broad range of training needs and technology and market forces guarantee that the technology will continue to improve over time.

Conclusions

Serious Game technology is an effective means to meet a wide variety of tactical training requirements and is particularly well suited to developing the cognitive skills necessary to turn a team of experts into an expert team. To take advantage of this capability, SGs need to be included as part of blended training solutions that can cost-effectively meet the psycho-motor and affective training requirements as well. In stand-alone mode, the games appear to be best suited from individual up to company level, however, when used in combination with other virtual and constructive simulations may well assist in the collective training of larger groups.

Returning to the original question posed in the title of this paper: Games – just how serious are they? The answer is very serious. So serious in fact that it may not be appropriate to call them games at all. Although not described in this paper, some training establishments may have difficulty accepting games as credible training aids. We could of course call them wargames, or desktop immersive trainers, however the authors of this paper believe that it is very natural for human beings to learn through play and the use of games, albeit for some very serious purposes, is an obvious and natural fit for tactical training.

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Modeling Human Behavior:

What the National Research Council says, what Marine analysts need to consider

Modeling Human Behavior: What the National Research Council Says, What Marine Analysts Need to Consider

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Introduction: Problems with Modeling Human Behavior

There's a long way to go before the Department of Defense can model human behavior well enough to support the analysis of irregular warfare (IW), according to two books published this year by the National Research Council (NRC). The nonprofit institution, which exists to provide technical advice to the federal government, published "Behavioral Modeling & Simulation" in July. Earlier this year, the NRC published "Human Behavior in Military Contexts," which primarily addresses training but still considers analysis.

The subject of the books is a vital one, because it's likely Marines will face IW for the foreseeable future. The books command more attention than typical documents because the NRC produced them. The NRC's authors are respected scholars, and the NRC emphasizes grand research issues rather than specific problems. To see two books come out in one year on a specific military need is unusual good fortune.

Both books revolve around understanding human behavior, which makes them relevant to analysts who have been exploring how to apply social sciences to the study of IW. Analysts will find the most value in "Behavioral Modeling & Simulation," which has a number of recommendations, including these:

1. **Improve the theory underlying models of human behavior.** Current models typically have inadequate theory.
2. **Be ready to account for and accept uncertainty and change.** There are important things we won't be able to know. And there are important things we will know initially but won't understand once population behavior changes.
3. **Research how to collect data for behavioral models.** Getting data suitable for behavioral models is very difficult, and modelers are prone to misunderstanding the relationships between behavioral data and behavioral models.
4. **Make sure that a federation of behavioral models rests upon compatible assumptions.** All the parts in your system diagram may appear to make a coherent whole. And the connections may permit each node in the network to "talk" to the others. However, where human behavior is concerned, different researchers can have radically different assumptions. Failure to maintain harmony with the assumptions is likely to produce meaningless results.
5. **In the Verification, Validation, & Accreditation (VV&A) process, there needs to be a special method of validation devised with behavioral models in mind.** You can't use the validation techniques you would use for a physics-based model because you can't test against the real world the way you can with laminar fluid flow or falling bodies.

Social Sciences

It may sound a bit naïve to say you're "reviewing social science," given the number and complexity of disciplines that qualify as social sciences, observed Dr. Jim Stevens of OSD PA&E. Nevertheless, he continued, it's necessary to develop a basic understanding of the relevant principles from the social sciences before attempting to create behavioral models.

This is reasonable advice for Marine analysts to follow as they contemplate what the NRC says about modeling human behavior. Analysts might see potential in such models, but right now the requisite knowledge isn't ready for prime time.

Definitions

The social sciences and the military are notorious for having revolving doors of misleadingly precise jargon. Throughout this paper, terms such as "behavior", "social sciences", and "irregular warfare" are used loosely. It's difficult enough to summarize the essence of what experts are doing in these fields. It's inconceivable that a brief paper can standardize nomenclature for DOD or a significant chunk of academia.

Even if we set aside the social sciences and focus strictly on DOD labels, we witness unsatisfactory descriptions that sometimes resemble shorthand for incomplete laundry lists. This array of acronyms and abbreviations includes: IW; Counterinsurgency (COIN); Counterterrorism (CT); Diplomatic Informational Military Economic Financial Intelligence Law Enforcement (DIMEFIL); Political Military Economic Social Infrastructural and Informational (PMESII);

Military Operations Other Than War (MOOTW); and Security Stability Transition and Reconstruction (SSTR).

This paper's refusal to be strict about terminology stems from IW's "squishy" nature. As an upcoming RAND report will note, even a basic line between terrorism and insurgency is a blurry line.

Marine Operational Concept

The Commandant of the Marine Corps, Gen. James Conway, released "The Long War" in the past year. He described his 36-page document as an "operational employment concept." He outlined a variety of problems Marines must be ready to face, and each one of these problems would be easier to tackle with a strong understanding of human behavior. These problems include:

- Various forms of IW, e.g., terrorism
- Ideological or religious extremism
- Ethnic polarization
- Poorly governed or ungoverned regions
- Weak economies
- Poverty
- Health crises
- Competition for resources such as water or energy
- Demographic problems, e.g., "youth bulge"
- Environmental problems, e.g., a tsunami
- Crime

Each of the problems Gen. Conway highlights is an asymmetric challenge – what the blue side does usually differs from what the red side does. This is challenging for the analyst. It means having one set of metrics to judge how effective blue is, and another set of metrics to judge how effective red is. As a group of panelists recently assembled by RAND observed, the conflict between the US and Osama Bin Laden vividly illustrates an asymmetric conflict. He makes small investments in attempts to cost us lots of money. We make large investments in attempts to kill him, kill his minions, and win over fence-sitters. Either way, human behavior plays a large role. Osama hopes the US public will grow tired of war. We hope fence-sitters will choose peace over extremism.

Counterinsurgency

Influencing human behavior is at the root of most ideas about counterinsurgency. By most counterinsurgency theories, blue and red may use entirely different methods, but each seeks to bring the population over to its side. The population may act out of fear, love, or some other consideration, but insurgents and counterinsurgents usually stake their hopes for success on the behavior of the population. This raises some questions for the analyst, such as:

1. How do you evaluate the population's opinions and behaviors?
2. If something affects the population's behavior, how long does that effect hold up?
3. What, exactly, is the "population"?

The questions that make counterinsurgency so difficult were at the heart of a recent discussion hosted by the Center for Naval Analyses. The toughest questions were asked by Dr. David Kilcullen, considered by many the world's leading expert on counterinsurgency. He practiced counterinsurgency in Australia's army, he served a year in Iraq as Gen. David Petraeus's counterinsurgency adviser, and he currently serves as the counterinsurgency adviser for Secretary of State Condoleezza Rice.

"Is counterinsurgency a strategy?" he asked. "Is it an operational art form … or is it just, in fact, a set of tactics?" This is a "question a lot of us are worrying about in the policy community," he said.

With so much uncertainty regarding the most basic questions, analysts must take great care as they dig into trickier questions.

While physicists, chemists, and engineers can build steadily on the observations of peers and predecessors, analysts of counterinsurgency have a harder time working with lessons from the past. There are always nagging questions about whether the things we've seen before are different from the things we'll see next. As Dr. Kilcullen pointed out, you see this problem when people try to draw extensively from successful British counterinsurgencies in Malaya and Northern Ireland. There may be a "fundamental difference between conducting counterinsurgency in your own country or in a colony versus conducting counterinsurgency in somebody else's country," Dr. Kilcullen said. The key difference, he continued, is psychological. When you go to a foreign land and conduct a counterinsurgency, "everyone knows you're leaving" sooner or later.

Uncertainty

While policy makers and operators must deal with uncertainty regarding strategy, doctrine, and tactics, analysts must deal with uncertainty regarding behavioral theories and behavioral data. As the NRC observed in "Behavioral Modeling & Simulation," you typically lack the data you need to model something such as a terrorist network. You probably won't know how closely your model matches the part of the world you're examining. You might not know if the scope of your model is appropriate for the scope of the problem. Lastly, some of your initial understanding will diminish as people change their behavior and their institutions.

Theory

Theories about human behavior tend to be neglected, the NRC argues in "Behavioral Modeling & Simulation." This happens in academia as well as in DOD because funding favors "doing" rather than "thinking." The unfortunate result is bad conceptual models. While modeling has the allure of being tangible, "strong theory and a clear specification of purpose" are far more important to understanding human behavior than a model with lots of "features and variables," the NRC said.

This problem is often apparent at both DOD and academic conferences. If the subject is modeling human behavior, it's common to find more modeling experts than behavior experts. As one person observed at a recent conference hosted by National Defense University, we don't begin our analysis by asking the most basic question: "What's the problem?" As someone else observed, it's as if we wish to skip over the problem statement, skip over the application of theory, and skip over the careful collection of data. "We rush to quantify what we don't understand," he continued, and we behave as if the act of making a model can somehow "ratify" the ideas the model represents.

It's unsettling that behavioral models still have weak theory. The NRC identified this problem in 1998 when it published "Modeling Human and Organizational Behavior."

While behavioral theories are abstract and difficult to pin down, they are an unavoidable issue in the practice of IW. For example, in "The Long War," Gen. Conway gives an example in which the Marines may find themselves providing "visible forward presence" to provide a country with "economic stabilization." An analyst supporting this type of endeavor has to understand the relationships between security, foreign military forces, and the economy of a host nation. These are theoretical matters.

Similarly, Gen. Conway wrote that the Marines may find themselves in a country suffering from economic decline, poverty, corruption, epidemics, and ethnic strife. The analyst assessing which problem to attack first must have a sound theory to guide him.

An analyst can't pull theories from a database and plug them into a model. In "Human Behavior in Military Contexts," the NRC argues that understanding behavior is difficult, and answers vary from region to region. For example, the NRC says you would need psychologists, economists, neuroscientists, and anthropologists to understand "cultural variation in basic processes, such as trust, reciprocity, cooperation and competition."

"It's the Data, Stupid"

The behavioral data that can be collected is often inconsistent with the data requirements for a behavioral model, the NRC lamented in "Behavioral Modeling & Simulation." While certain problems with behavioral data will always exist, others are correctable, the NRC said. In order to get past garbage-in and garbage-out, modelers need to share more of their responsibilities with Subject Matter Experts. Experts in social sciences and experts in counterinsurgency need a bigger role in creating models, identifying variables, and choosing assumptions.

The NRC doubts there are universal laws of human behavior and social structure. Even if such laws existed, the NRC adds, it would be difficult to codify them and compile empirical data, and it would be "unlikely that they could be represented as closed-form equations." In other words, there are no quick fixes for behavioral data. Collection and use of such data require care and judgment.

Social scientists wrestle with the problems of behavioral data frequently. They know that if you interview someone about what he values, he might say one thing and even mean what he says. But if you observe him, you might see that he the way he spends his time doesn't square with what he says is important to him. Alternatively, you might collect data regarding some sort of social change, but it might be very difficult to tell whether the data reflects the actual mechanism of change or merely reflects a superficial manifestation of the change. As yet another example, you might have a lot of data about a population at peace, but the story those data tell might say nothing about how the population would behave during a war or a disaster.

A social scientist can have a lot of data and still lack the data he needs. There are many different types of problems – economic, political, religious, ethnic, etc. These problems

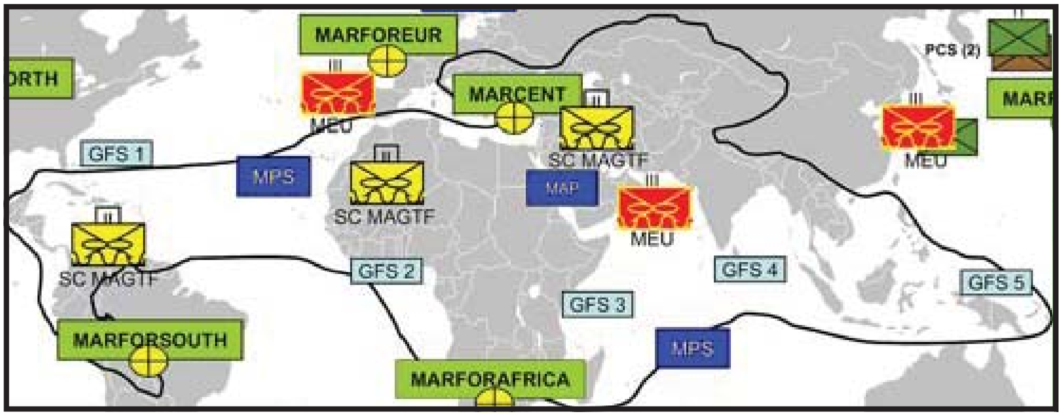

Figure 1: Regions of potential instability (from "The Long War").

might exist in a variety of combinations. There are also many countries that are potential battlegrounds, and many of these countries look quite different as you move from one region to another. General Conway's "The Long War" includes a map highlighting regions of actual or potential instability. The circled region of the map gives analysts more than 100 countries to consider (see Figure 1 below).

The data challenges shift as you move from one country to the next and from one type of IW operation to another. As an example of an IW operation, Gen. Conway says the Marines might find themselves working with Liberia's "ethnically fractious military" in order to make it more professional. As another example, Gen. Conway says the Marines might find themselves in Kenya, working with Non-Government Organizations to deliver humanitarian relief following a severe drought. Both operations might be characterized as IW operations supporting the Global War on Terror. But an analyst probably would need two entirely different sets of data to study these problems. It's likely that none of the data relevant to the Liberia operation would be useful for the Kenya operation, and vice versa.

The Army's Human Terrain System currently shows how easy it is for social science data from IW to become a collection of stovepipes. Social scientists and supporting personnel deploy to Iraq and Afghanistan in teams. They typically support battalion commanders. In accordance with counterinsurgency doctrine, these commanders function with decentralized authority. Consequently, the Human Terrain teams aren't coordinated in their data collection. One battalion commander might use his Human Terrain team to compile biographical narratives on a village's leaders. Another battalion commander might use his Human Terrain team to make population estimates and keep notes on the economy. The result is plenty of data, but very little in the way of systematic data collection or data standards.

Behavior

The behavioral questions interesting DOD have changed dramatically in 10 years. When the NRC published "Modeling Human and Organizational Behavior" in 1998, the focus was conventional. Typical behavioral questions involved how to train submarine crews, how to model the pilot of an aircraft, and how to model the commander of a tank unit.

If it was difficult to model members of a military following their doctrine, then it's bewildering to model civilians as they determine their goals, make plans, learn, make decisions, and so on. And cognitive processes aren't straightforward, mechanical, or purely rational, the NRC warns in "Behavioral Modeling & Simulation." The NRC says "understanding emotion is critical for understanding cognition."

Because cognition is complex and because emotions muddy the waters, the NRC says it's common to observe seeming paradoxes, such as group behavior unlike individual behavior. A classic example of this is a riot. Riots, by definition, involve a lot of people, but most participants wouldn't loot or behave violently by themselves.

Generalizing about behavior is also difficult, the NRC says in "Behavioral Modeling & Simulation." As examples, the NRC notes that markets, democracies, and traffic laws work differently in different parts of the world.

Macro, Meso, Micro Models

The analyst has to be prepared to attack behavioral modeling at three levels. Macro models address unemployment, crime, education, poverty, etc. Micro models address individual cognition, e.g., psychological considerations such as emotion or rational choice. But, as the NRC says in "Behavioral Modeling & Simulation," sometimes the answer lies in the interactions between select portions of the macro level and select portions of the micro level. On these occasions, the analyst needs a "meso-level" model.

Agent-Based Models

The value of agent-based models is their ability to explore "emergent behavior" – behavior that wouldn't be predictable based on examination of the entities by themselves. Sometimes the whole is different from the sum of its parts, and agent-based modeling is a good way to look at how interactions between agents generate unexpected results.

The key with agent-based models is to be careful about tradeoffs, the NRC says in "Behavioral Modeling & Simulation." The sophistication of an agent in an agent-based simulation is usually inversely proportional to the number of agents, the NRC says. The analyst is asking for trouble if he tries to have it both ways – a model with lots of agents possessing many variables.

It's worth noting that agent-based models work best when behavior is routine or benign. For example, there are a number of useful simulations that predict pedestrian movement, traffic movement, etc. Such simulations can also track the spread of a disease until news of an epidemic breaks out. Once the news is out, however, the simulations aren't very useful. As a speaker at the World Congress on Social Simulation observed, when people realize there's an epidemic, you have a panic on your hands, and no existing simulation is good at modeling human behavior during a panic.

System Dynamics Models

System dynamics models emphasize relationships and look familiar to engineers. They have blocks, inputs, outputs, and feedback loops. System dynamics models rest upon differential equations, and as the NRC points out, there can be problems when modelers work with social scientists lacking strong mathematical backgrounds. Also, as the NRC pointed out in 1998, most social and organizational theories are verbal descriptions. Marrying a complicated verbal description with elaborate mathematical analysis is destined to be difficult.

Network Models

Network modeling emphasizes connections from one point to other points, i.e., from node to node. Social network analysis, which is closely related to network modeling, has many success stories, as the NRC points out in "Behavioral Modeling & Simulation." These successes include helping DOD find Saddam Hussein, helping detectives solve crimes, and helping singles with Internet dating.

Network models and the analysis they support look at connections to better understand groups and individuals within groups. The NRC explains a number of pertinent terms to better elucidate network analysis. Some meaningful terms include:

- **"Closeness Centrality":** This is the sum of the distances from one node to all other nodes. This can help explain which individuals are ensconced in a community and which individuals have ties beyond the community.
- **"Betweenness Centrality":** This describes a node that is on many of a network's short paths. Typically, such a node is important to keeping other nodes informed, which means disruption of this node can disrupt the whole network.
- **"Eigenvector Centrality"**: This describes the extent to which a node is connected to many other well-connected notes.
- **"Active Area":** An "Active Area: is a cohesive subset of nodes. It has many ties within the cluster and few ties outside the cluster.

Network analysis, like any analysis involving behavioral models, has its challenges. For example, it's difficult to research what terrorists are doing, which means it's difficult to know whether a network model has too few/many nodes or connections. What's more, the NRC notes, it isn't known what the impact is when an analyst studies an inaccurate model of a terrorist network.

Another problem facing network modelers is "network overlap," according to Dr. Bill Young, a Navy analyst who has spent the bulk of his career as an anthropologist. "Network overlap" occurs when one person shows up in two or three networks. This happens frequently, and when it does, it's often necessary to know how the person prioritizes his allegiances to the various networks. Understanding these allegiances can be very difficult for the analyst or for the researcher gathering data.

Capitalizing on the strengths of network analysis while minimizing the weaknesses is a topic Jana Diesner addressed skillfully at the recent World Congress on Social Simulation. As she put it, the analyst can't remove himself from the analysis. He must plunge into the model and take ownership of the conclusions. Analysis involving social science is complex, rests upon many assumptions, and includes significant uncertainty. There is simply no way to use a black box to get answers. The analyst can't hand the problem off to the model; instead, the analyst must constantly work with the model and help mold the product that emerges from the model. Diesner used examples of network analysis involving millions of Enron emails to show what kinds of discoveries can be made and the importance of an analyst willing to exercise judgment during the course of a study. Diesner's observations deserve consideration on their own merits, but they carry extra weight because she is working on her doctorate at Carnegie Mellon University under the supervision of Dr. Kathleen Carley, who helped author "Behavioral Modeling & Simulation" for the NRC.

V, Validation, & A

The thorny part of the VV&A process for behavioral models is validation. How do you establish that the model tells you how people would behave in the real world? As the NRC says in "Behavioral Modeling & Simulation," traditional validation – something akin to the validation for a physics-based model – is "difficult if not impossible to fully achieve." However, as the NRC also says, this isn't an excuse for not doing anything. Instead, a new approach to validation is in order. A behavioral model should be judged on how well it narrows the range of possible outcomes for a situation. Validation should include many experts, and it should be conducted in light of similar models and relevant studies. A behavioral model won't be predictive, but it can be informative.

Conclusion

We, as Marine analysts, must be skeptical of off-the-shelf solutions. We can't treat behavioral models as black boxes or crystal balls; behavioral models simply aren't that good. Instead, analysts must incorporate their judgment and their understanding into whatever answer is coming out of a model.

In addition to lacking off-the-shelf models, we lack off-the-shelf methods. There is no cookbook recipe for understanding human behavior. Many IW problems are unique and require tailored analysis, observed Scott Moss during the recent World Congress on Social Simulation. As convenient as it would be to take theory off the shelf and start modeling, you can't let abstractions obfuscate the particulars of the region you need to study, said Moss, who was educated as an economist but has spent his career as a sociologist. "If you want to study conflict in Baghdad," Moss said, "why don't you start by studying conflict in Baghdad?"

The quest for an all-purpose tool or an all-purpose method has always charmed DOD, but the NRC specifically warns against this temptation in "Behavioral Modeling & Simulation." Citing the overly ambitious master plan devised by the Defense Modeling & Simulation Office in 1995, the NRC says that "developing a universal ontological standard for model creation is impractical."

When we bring modeling expertise to bear on the analysis of IW, we must remember it is just that – modeling expertise. Behavioral modeling requires what its name implies it requires – behavioral expertise *and* modeling expertise. What's more, behavioral expertise depends on the problem. If you're trying to understand market behavior, an economist can probably help you. If you're trying to understand migration in the face of genocide, an economist probably can't help you. Modelers "operating outside their area of expertise" have a tendency to create variables "in a hodgepodge fashion," the NRC says in "Behavioral Modeling & Simulation."

It also seems possible that modelers operating outside their area of expertise have a tendency to do what makes them comfortable, regardless of its applicability. This impression arises from time to time when system dynamics models are pitched as solutions for IW analysis. It can seem a bit odd when the behavior of people is studied with the same analytical methods applied to an electrical circuit full of capacitors or to an oscillating weight attached to a spring and a damper.

Along the same lines, there sometimes seems to be a false air of scientific precision when models are touted as being "neural network models." The definition of this label sometimes seems to exist only in the mind of the beholder. Some "neural network models" claim to be models of a human nervous system. Others claim to be models of something else that's analogous to a nervous system. Either way, the claims should be met with careful scrutiny. Physiologists believe the human nervous system may have as many as 100 billion neurons. It would be difficult to take that complex prototype as a guideline for creating a meaningful model.

The fundamental question we face in the analysis of IW is when to take a wide view and when to take a deep view. The tradeoffs are obvious – a wide view means a shallow view, and a deep view means a narrow view. This is a difficult question. The number of potential trouble spots on the globe and the variety of social sciences seem to be a vote for employing a wide lens. On the other hand, the complexities of human behavior seem to be a vote for drilling deeply into a problem. Ultimately, it seems that drilling deeply is too risky. That means putting all the eggs in one basket. History shows that nations are very bad at predicting what the next war will look like, and often nations struggle to predict where the next war will be.

To fully grasp the risks of drilling deeply into a single problem, consider what "Behavioral Modeling & Simulation" said about agent-based modeling. As the NRC put it, "detailed, sophisticated ABM frameworks that produce actionable results often need to be developed by a team working collectively for three to five years." Do we know where we'll be fighting in three to five years? Do we know whether the problem will be economic, religious, ethnic, or something else?

We need to trade depth for agility and flexibility. That doesn't necessarily mean most problems will be analyzed with models. As Dr. Bill Young, a Navy analyst, said, the answer to a quickly arising problem might be something simple, like a survey of SMEs or a focus group of SMEs. That approach is far quicker than modeling, and the expertise is more firmly rooted in the specifics of the problem.

On those occasions when models are applied to IW, the practical move is to use simple models understood by the analysts involved.

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