

CONDUCTING SYSTEMS ACQUISITION WITH SIMULATIONS IN THE 21ST CENTURY

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Abstract

As the new millennium approaches, a question begs to be answered; how can the modeling and simulation technologies developed over the past fifteen years be applied to provide synthetic solutions to reduce the cost of systems acquisition? In the past year the call for simulation based acquisition has continued to expand. The idea of using simulations to support acquisition is not new, novel, or revolutionary. Supporting acquisition with simulation is sensible but also low risk and therefore provides potentially only a minimal reduction in acquisition costs. The opportunity before the community today is to morph the paradigm of the simulation role from one of supporting to one of conducting acquisition. Conducting acquisitions using simulation brings forth a whole new range of issues. It also transforms a low risk approach to a higher risk with the potential for significant cost reduction. Development of thought leadership by the simulation and acquisition communities to address this opportunity is required as DoD moves into the 21st Century. The problem is very broad and the issues are many. This paper focuses on the challenges of conducting test and evaluation through simulation for systems acquisition. The keystone issue here is to define a process which could evolve a simulation architecture that will be accepted as a tool for conducting portions of test and evaluation beyond merely providing a supporting role. The results of our efforts will be valuable to Program Managers (PM) during the Milestone II to III phase of their system's acquisition cycle. Our approach is based upon working through such a process of defining architecture and simulation specifications to support the operational test and evaluation program for PM Grizzly. As a result of our effort to develop this architecture a need arose to also define a structured methodology that would help us to arrive at a useable result. Through the process put forth in this paper we are confident we have developed a useful methodology that will permit PM Grizzly to conduct segments of the Grizzly operational test and evaluation in simulation. This structured methodology is generic enough that it is capable of supporting other acquisition projects as well.

Biographical Sketch:

Kevin Roney is a Senior Associate with Booz-Allen & Hamilton and the Project Manager for the US Army's Warfighting Analysis & Integration Center (WAIC). He has 15 years of Systems and Software Engineering experience. Kevin has worked in the Advanced Distributed Simulation business for more than eight years. His previous experience includes managing development of simulation databases for the US Army's Topographical Engineering Center and performing as a Senior Systems Engineer on the DARPA War Breaker Program. Kevin holds a B.S. in Nuclear Engineering from the University of Missouri-Rolla and a M.S. in Engineering Management from the University of Maryland.

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INTRODUCTION

The purpose of this paper is to discuss an approach for leveraging simulation in the systems acquisition process specifically focused on test and evaluation (T&E). Modeling and simulation (M&S) is very much a part of the current systems acquisition paradigm, however, The current T&E paradigm misses an opportunity to truly leverage the value of information technologies. This paper addresses the positive impact that a change in the process of how tests and evaluations are conducted could be realized. As we worked with PM Grizzly on defining a role for simulation in the T&E process, we began to realize that the real challenge was not solely in integrating the technology, but in changing attitudes within the community as well.

Much has changed in the past 25 years since the Parkard commission set forth in revising the acquisition process. The most significant changes have been in technology. Today's desktop computers out perform much of the whole of the computational power of 1970. What hasn't changed very much, however, is how DoD conducts acquisitions. Information technology has significantly impacted the administrative aspects of the acquisition process. We now have web sites to archive and display documentation, and animated presentations to explain programs. There are indications that some changes are occurring in the paradigm. An example is the use of physics of failure (PoF) technology. The whole area of reliability engineering can have a great impact on systems acquisition at both ends of the life cycle. PoF can help to address potential design flaws as well as reduce the complexity of reliability testing. These changes have come recently (since 1996) and are limited in scope.

Another issue at hand is that DoD was once a driving factor for technology. Much of what the commercial industry benefits from today came through DoD investments. Clearly DoD does not have the level of resources it had in the past, however DoD still has the need and could continue to greatly contribute to developing new technology. An area such as PoF advancements that can help the DoD acquisition process can also give US manufacturers a leg up on it foreign competitors. By leading the way to solve the difficult challenges of applying simulation technology to test and evaluation, DoD can continue to provide benefit to commercial industry.

CASE FOR THE OPPORTUNITY

What is the opportunity?

In past ten years both computer and networking technology has evolved to a point in both price and capability to provide effective tools for changing the acquisition process. We are at a break point where it becomes feasible to conduct operational test and evaluations using simulations. Today at points within system's acquisition, simulations are used to conduct various evaluations such as an Analysis of Alternatives. However, the leverage points for such uses of information technology are small in terms of cost savings when compared to cost of field-testing. If we can move the operational testing paradigm for use of simulation from "supporting" to "conducting" tests, serious costs saving could be realized. Our proposed concept is not to conduct all tests using only simulations but to apply the technology at points where greatest benefit can be realized. In an operational test a hybrid approach of linking the live and virtual environment is an example of applying the technology to gain the greatest benefit. In this context the virtual test world allows evaluations of systems in a more robust

and realistic set of conditions. In a real world test you would not expose the operator or system to a high-risk situation that they would experience in combat. Exposure of an operator or system to high risk, life threatening conditions like those faced in actual combat cannot be done in live testing. So in many ways by conducting tests with simulations you have the potential to test a system more rigorously. The synthetic environment created with simulation provides a viable way to test under these type conditions. Again we stress that the intent is not to eliminate live testing.

Even as Chrysler strives to reduce the design cycle with simulations they have realized an increase in live vehicle testing. Some of this is due to federal regulations, but some, relates to the need to validate computer simulations. A challenge we face today regarding conducting tests using simulation is that we don't have the experience base necessary to make this a viable alternative. We don't as a rule conduct tests to validate the computer simulations. Therefore the state of simulations today to conduct any operational test is questionable. Additionally, there seems to be a gulf between the T&E and simulations community. Each practitioner understands their own world, but not necessarily the other's. The challenge is not just for the T&E community to embrace the idea of simulation based test, but for the simulation community to understand the tester's concerns about simulations.

During this decade too often the simulation community made great assertions about simulation's capabilities, which proved false. The technology is now capable of meeting the challenge. The question is whether the opportunity can be realized. The process to move forward should be a crawl, walk, and run approach. If the T&E community embraces the concept of a virtual testing world, we can truly begin to change the system acquisition paradigm. We can tighten the spiral development process. We can realize cost savings because we will only need to conduct live tests to validate simulations needed for operational testing. Over time as the simulation-test-simulation process is repeated we can create tighter tolerance, better simulation, at a reduced cost. Additionally, computational power will continue to improve providing better and more realistic virtual worlds. Simulation as a tool provides the ability too more effectively and

efficiently train soldiers in an environment that is realistic enough to have a profound impact on our warfighting capabilities. By using simulation environments to development new systems we bring together training with early systems development to reduce the time associated with development and fielding of new systems. In a simulation based acquisition framework we move ourselves away from the traditional waterfall approach to the preferred "spiral" approach, figure 1.

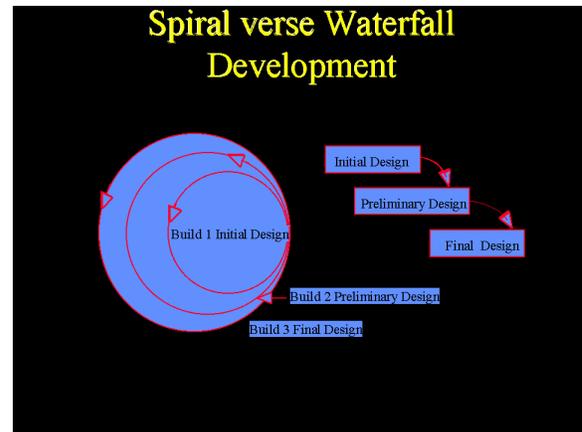


Figure 1. Spiral versus Waterfall Development

This provides the Warfighter with a continued technology edge and overall dominates maneuver force leverage. We begin to see the impact the simulation based acquisition can have for the Warfighter, but it also has a positive effect in cost associated with procuring systems.

Why is it an opportunity?

The opportunity to change how systems acquisitions are conducted has continued to develop over the past five years. Work continues to progress in using simulation during the concept development phase of an acquisition. The real challenges for simulation based acquisitions (SBA) are in the test and evaluation cycle of a new weapon system. When a system reaches this phase of the acquisition process a significant investment of time and resources has been made. The expectation is that all of the work leading up to the operational test has built a solid system for the warfighter. But experience has shown there is still risk. Risk, which DoD often is unwilling to accept. Testing in a realistic simulation world would help to significantly reduce those risks. This can be done very early in a spiral development approach.

An additional factor is the cost associated with conducting operational test. For M1A2 Abrams tank the cost of operational test was over \$34 million. At a time of limited defense spending significant expenditures for test cuts into overall service resources. Often readiness becomes a billpayer. DoD's cannot continue to conduct systems acquisition as has been done for the past 25 years and at the same time continue the current operational tempo. To meet the Joint Vision 2010 the U.S. military needs to continue to acquire more advanced systems. However, there must be a give and take within a stable but reduced funding environment. Most recently that take has been readiness. With today's operational tempo, readiness is the least desirable area to decrement, especially when technology is available today to reduce acquisition costs by conducting some tests using simulations.

Finally, real SBA is a powerful means of tightly coupling the Warfighter's need with the acquisition process. "From the perspective of a weapon systems contractor, benefits of virtual prototyping include: (a) tighter coupling of operational requirements with developer implementation concepts, (b) introduction of a rapidly re-configurable tools for refining system requirements early in the systems development cycle, and (c) a means for improving the visibility of the system requirements analysis process" (Brown and Lavender 1992).

One example of how this opportunity is being pursued is the Army's Grizzly system. By using modeling and simulation the Grizzly may realize a greater than \$80 million cost savings in conducting its operational test. This is to be achieved by using accredited simulations and simulators to reduce the number and type of real systems needed to meet operational test requirements

Before looking at the technical approach and methodology associated with Grizzly, it may be useful to review where we have been to set the stage for where we are headed.

HISTORICAL PERSPECTIVES

T&E History

T&E policy and practices in support of the DoD materiel acquisition process has remained relatively unchanged for over 25 years. In the early 1970's a wide ranging review of the acquisition process was conducted by then Deputy Secretary of Defense, Mr. David Packard. Of the many initiatives coming out of the review, one established agencies for operational test and evaluation (OT&E) independent of service commands responsible for new system development. Another established the policy that technical uncertainties must be resolved during development, not production. The Packard review concluded that OT&E had been generally inadequate with little or no OSD oversight of the Services. The decision to produce only after development was completed as verified in testing was a fundamental change from the practices of the 1960's and in May 1971, the present course was set.

DoD acquisition policy as we know it is based on Office of Management and Budget Circular A-109, April 1976. DoD's implementation has resulted in the Life Cycle Systems Management Model with sequential phases and milestone decision reviews. While the names of the phases have changed over time, the activities and the thrust of testing that occurs within the phases has remained constant. Technical or developmental testing (TT/DT) occurs throughout the life cycle and OT&E supports MS II and MS III decision reviews. For major programs the reviews are at the DoD level. Others are accomplished within the Services. In either case, independent T&E, is a key input in the decision making process.

The role of M&S within the acquisition process and specifically with regard to testing has grown over the years. In the late 70's and 80's M&S was employed early in the development cycle primarily to evaluate concepts and requirements. In a 1986 study, "T&E Support for Systems Acquisition Decisions", Charles Watt observed early in the life cycle of a new system, computer simulations can be expected to provide most of the system evaluation information. As the system matures, simulations continue to play a significant role and should be updated and

validated using feedback from subsystem and prototype testing. He further observed their value as a system evaluation tool improves with the passage of time. Finally, he highlighted two issues with M&S that continue to dictate the degree to which they are used today, realism and believability. Realism is important because the validity of the results of the simulation is directly related to how realistically it represents the system and its environment. Closely related to realism is the acceptance or believability of the results obtained from M&S. Decision makers generally feel more confident about system evaluation data obtained from hardware prototype testing than a computer simulation. Believability is enhanced when the simulations have been validated by corroboration with the results from physical testing. (Watt 1986)

Fast forward 10+ years to the present. Realism and believability are at the core of simulation's role in OT&E. The concern for verification, validation, and requirements for accreditation, have been with us for quite some time.

Current DoD policy encourages ever increasing use of M&S in support of OT&E and the acquisition process. While on the one hand encouraging use, policy also limits use by stipulating that an operational evaluation supporting a decision to proceed beyond Low Rate Initial Production may not be based "exclusively on computer modeling, [and] simulation..." (DoD 5000.2-R, 3.4.5, p 21)

Hence the T&E community today touts their use of M&S in "support" of test design, test preparation, overcoming test limitations, reducing test cost, and enhancing evaluation. Engineering models guide the selection of test conditions. Systems simulations are used to scale down test scenarios, and combat simulations help select operational scenarios. Safety considerations and peacetime restrictions are mitigated. Overall thinning out unnecessary live assets, virtual play of adjacent units, and automation of some human input can reduce test costs. Examining other conditions in simulation, conducting baseline comparisons, and simulating alternative courses of action to assess potential enhances evaluation. The bottomline paradigm, however, is M&S does not substitute for test of the live system.

Technology Paradigm Shift

The concept of a technology paradigm shift is relatively new. Essentially a paradigm shift is a "fundamentally new way of looking at something" which is "often necessitated by new developments in science, technology, art or other areas of endeavor" (Tapscott and Caston). As Lord Cromwell has been quoted saying "you get what you got when you do what you did". This is very true for technology. If all simulation based acquisition offers is doing what we did before faster then we'll have what we had before just faster. For Chrysler the impact of information technology wasn't realized until they changed their design process. The same is true for Boeing. If these companies hadn't shifted to a new approach they wouldn't have made nearly any of the gains realized. For SBA some paradigm shifts are going to need to occur if DoD is going to more fully realize any real advantages to in using simulation technology. If DoD continues to take the view that operational test can only be conducted using live assets, then we'll still get the same process we have today, only enhanced with newer computers.

Bradley A3

In October 1996, the Army's Simulation, Training and Instrumentation Command (STRICOM) in coordination with the Army's Operational Test and Evaluation Command (OPTEC) initiated the Feasibility Analysis Study (FAS) of the M2A3 Synthetic Environment Operational Testing (SEOT) This effort was undertaken to evaluate the feasibility of performing operational testing and evaluation in the synthetic environment (SE) by doing "side-by-side" comparison of test results using the Bradley M2/M3A3. As a part of this analysis, planning and resource requirements were identified to support operational testing through IOT&E of the M2/M3A3. The data collected in the SE was expected to be used by the test community to evaluate the maturity and capabilities of the SE with respect to supporting future test events. The main objectives of the FAS were to (1) Assemble and test a SE capable of supporting operational testing (OT), (2) Demonstrate the utility of the SE in support of operational test programs, (3) Develop a test to be used for the side-by-side Operational Testing (OT) of the Bradley, and (4) Analyze and select those Bradley testing requirements supportable in the SE. Using the M2/M3A3 System Evaluation

Plan (SEP) as a primary data source, each of 407 Measures of Performance (MOPs) listed were reviewed to determine if the SE could collect data that could be used for evaluation. A candidate test list of 108 MOPs was identified. SE test architecture was designed composed of current technology and demonstrated in April 1997 (Alban, et al 1997) Additionally, a plan was developed to support the candidate test list of MOPs. Funding limitations precluded conduct of the actual side-by-side test, however, a subset, the SE for Live Fire (SELF) was resourced by OSD LFT&E.

The SELF effort investigated how to effectively augment live fire testing in a SE. In addition to generating synthetic data for comparison to actual live fire data, SELF sought to establish a reusable and reliable test architecture capable of supporting different platforms throughout acquisition, examine the utility of supporting live fire testing in the SE, and document recommendations for designing and evaluating live fire SE test methodologies. Initial results from testing conducted in 1997 and 1998 were promising. Final evaluations are being completed and will be presented at I/ITSEC '99 (Alban, et al 1998)

Commercial Use

Most have heard of the Boeing 777 or the Chrysler Intrepid success, but many probably don't know about the successful use of M&S technology to develop the Zip® disk. In the mid 1990's as computer technology continued its explosive growth, file sizes began to grow. One of the biggest contributors to this growth was graphics presentations. We have all developed these several megabyte size Microsoft Power Point slide files which aren't easily emailed and don't fit on a standard floppy disk. So the idea for a larger capacity floppy disk was born. The creators of Zip® technology did all of their hardware and software design, development and testing in a virtual environment. The Zip® disk went from virtual design to manufacturing without building hardware prototypes. The success of Zip® is seen in most everyone's office. This example is not to suggest that all systems could be acquired in such fashion. It is also understood that there is a big difference between a complex aircraft and a rather simple Zip® technology. But events like the Zip® development are stepping stones to addressing the more complex problems. At some point DoD

must begin to move toward this new paradigm to leverage technology not only within a new system, but in the way in which it is acquired as well.

Space Program

It is a "chicken or egg" story. One can easily argue that without the critical role played by M&S, America's space program would be nowhere near where it is today. At the same time, one could also argue that the space program has driven the development of computer hardware and software, basic components of M&S and the realization of its benefits. But the paradigm is unique in that space flight was simulated before it was ever accomplished.

Even though the requirements for manned simulators far exceeded state-of-the art when the first astronauts reported for duty in 1959, NASA "bet the farm" on M&S and required hundreds of training hours in the high fidelity simulators that were produced for each manned spaceflight program. Each crewman in the Mercury, Gemini, and Apollo programs spent one-third or more of their total training time in simulators. Lunar landing crews devoted over half of their training time to simulator work.

When preparing for the Mercury mission, experience with aircraft simulators was limited. While dangerous, new or experimental aircraft, were rarely tested at projected limits on the first flight. The X-15, for example, had numerous buildup missions before flights sent the plane to the edge of space. In rocket flight, however, spacecraft are pushed to the limits of stress and endurance from the start of ignition. Crude by today's standards the Mercury Procedures Simulator was powered by analog computers calculating equations of motion and providing signals to cockpit displays.

Preparing for the more complicated Gemini missions required the use of digital computers in the simulators. The Gemini program ushered in the concept of functional simulation in which the actual on-board Gemini mission computer was not installed, but its displays were activated or emulated by the three Honeywell computers driving the Gemini Mission Simulator. It was during this program when a motion-based platform became important to train docking

maneuvers. Additionally, Gemini simulations often included Mission Control and the worldwide tracking system.

With the Apollo program, NASA used 15 simulators to train the crews. They even went so far as to create a simulation environment for the last 200 feet of lunar landing by suspending a reduced weight simulator to give astronauts practice in controlling the lander in the moon's gravity. Another lunar landing simulator used a jet engine to permit free-flight landing. This simulator required a simulator of its own to keep the astronauts from crashing it! Mission simulators used networked computers, rather than single mainframes, and software became as important to the simulated world of Apollo as it was in the real world. (NASA 1997)

The Space Shuttle and Skylab programs are the benefactors of the earlier simulation work and today Joint Integrated Simulations for the Spacelab provide a high-fidelity, interactive simulation to train the astronaut flight crew, mission operations personnel, and hundreds of scientists located around the world. The fact is the "one small step" was taken over and over again in simulation, just as have most, if not all, the critical steps been taken in America's spaceflight experience.

TECHNICAL APPROACH

This section of the paper addresses the "how to" of putting together a simulation capability that will be capable of conducting operational test. In defining the technical approach experience was gained from the Defense Advance Research Project Agency (DARPA) Unmanned Aerial Vehicle (UAV) program. The UAV program used extensive simulation to help define requirements, select among competing contractors, and support design reviews. This UAV SBA experience to facilitated the development of an approach which to best defined the simulation requirements for the Grizzly Virtual Prototype System (GVPS). PM Grizzly is planning on using only two physical prototype vehicles for operational testing. This is a deviation from other recent acquisition programs like the Bradley-A3 where eight vehicles were used, or the Abrams M1A2, which used over 12. As mentioned earlier this approach is expected to avoid over \$80 M in program cost.

PM Grizzly is relying on SBA to provide and support simulations for system development and testing in order to help ensure that two prototypes will be sufficient. As an SBA initiative Grizzly is no longer focused at the early phases of the acquisition cycle but needs to create a leverage point between Milestone II and III. The program has many challenges to overcome. It will require an accredited simulation environment. It will rely heavily on standards and reuse, and it must be cost affordable. To accomplish these goals a detailed understanding of the requirements for the GVPS was required. Based on the UAV experience, a plan was needed to define the necessary simulation requirements to meet operational test objectives as well as be a guide GVPS development. This will be accomplished by the development of a GVPS Master Plan, Figure 2.

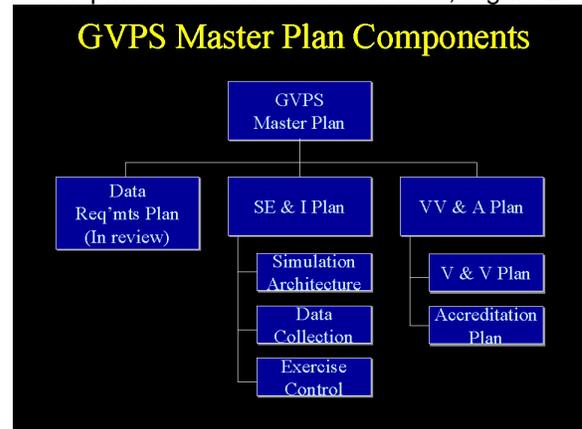


Figure 2: GVPS Master Plan Outline.

The plan consists of a three sections, data requirements (SE&I), systems engineering and integration and verification, validation, and accreditation (VV&A). The first and most important section is the data requirements. The information in this section will drive the requirements for the development of the GVPS. The approach used by PM Grizzly was to initiate an integrated product team consisting of Army agencies and support contractors as shown in Figure 3.



Figure 3. GVPS IPT team.

To define the data requirements for the GVPS it was necessary to determine what the test objectives would be for the Grizzly. During the IPT process it was concluded that the best source of information would be OPTEC's System Evaluation Plan (SEP). The SEP, now in draft for the Grizzly, provides the top level Critical Operational Issues and Criteria (COIC) and Key Performance Parameters (KPPs) for test. From these COIC and KPP a hierarchy of Measures of Performance/Measures of Effectiveness (MOP/MOE) is developed that becomes the foundation for defining the requirements for the GVPS. The challenge encountered here is that test plans for an operational test aren't typically finalized until about six months prior to the test. This provides insufficient time for defining requirements and then development of any type of credible simulation. At some risk, the draft SEP, and the Event Design Plan (EDP) used for the early user evaluation were used to define the GVPS requirements. As time progresses the data requirements section will be reviewed and updated as the SEP and EDP are revised. Figure 4 below depicts the approached used for

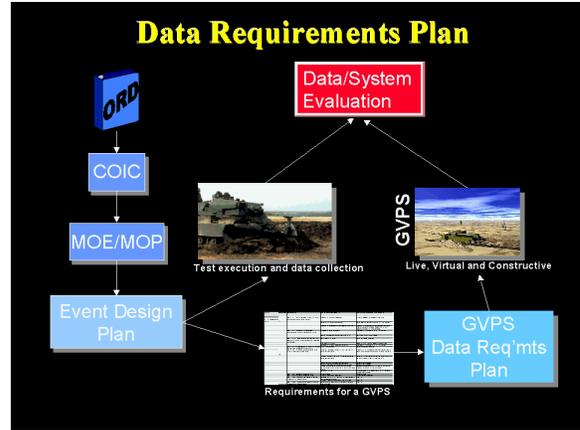


Figure 4: Data Requirements development process

the data requirements plan. The key to the plan is the MOP/MOEs. The level of fidelity of the GVPS will be matched to these MOP/MOEs as much as possible. All MOP/MOEs were assessed to decide whether the information would be provided primarily from the Live Environment, the Synthetic Environment, or a combination.

The next section to be development developed will be the SE&I Plan. The SE&I Plan will develop the overall synthetic environment architecture. Figure 5 is an early representation of what the potential architectures will incorporate.

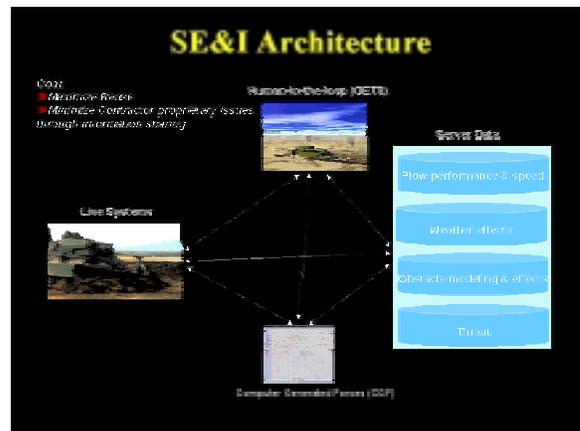


Figure 5: Conceptual GVPS Architecture

A critical part of the SE&I Plan will be the development of an interface requirement specification (IRS). The IRS will define how the various simulations, simulators, test vehicles, and data collection systems will interact.

The SE&I Plan will M&S standards such as SEDRIS. For technology risks reduction, and since the GVPS will be required to interoperate with other simulation federates the PM is stressing interoperability in the development approach vice extensive software infrastructure reuse across multiple programs. This appropriately places reuse at the High Level Architecture (HLA) level and helps to ensure that a product is available much faster than trying to build the GVPS in a one-size-fits-all infrastructure.

The final section of the GVPS Master Plan will be the VV&A Plan. The VV&A Plan will provide the guidance and process for developing the verification and validation documentation necessary for OPTEC to conduct accreditation. VV&A for the GVPS will follow guidance provided by OPTEC and appropriate Army Regulations and procedures (AR 5-11, and DA PAM 5-11).

CONCLUSION

The purpose of this paper was to put forth a case for evolving simulations in the 21st century to conduct test and evaluation as part of the systems acquisition process. Some in the test and evaluation community will differ with this position, which is understandable. To their credit the T&E community has been very successful in meeting the DoD T&E mission without the need to use simulation in conducting operational tests. However, as this paper asserts, there is evidence that an opportunity does exist and that the time is right to move forward in conducting operational tests and evaluations with simulations. The cost margin for SBA is at a point that use of simulations is less expensive than live testing. Simulation testing also allows complex evaluation in environments that live systems may only encounter during actual combat conditions. There are technical challenges such as data standards, but these challenges will be overcome if and only if we begin the process. For nearly two years SBA has been discussed at the policy level. Senior leaders are supportive, but implementation is conducted at the PM and test director level. For them SBA is only valuable if it addresses a need. The Testing for systems acquisition has been accomplished very successfully over the past 25 years. Many in the test community, however, seem to be using the paradigms that "if it's not broke don't fix it". The cost of testing during an acquisition is

significant and a more cost-effective approach is required. Change is not easy to implement. A paradigm shift is required at both the execution and policy levels for value of SBA to be fully realized.

For the new millennium the greatest success for systems acquisitions will come when the simulation and T&E communities can join forces in addressing the opportunity to conduct T&E using simulation technology. We believe that the approach outlined provides the means for development of simulations, which are robust and credible. If senior leadership support continues and the test community makes the effort to assist in the paradigm shift significant break through will occur.

Since PM Grizzly is stressing reuse in both product use and product development, the Grizzly program will benefit in many other ways from this aggressive simulation program. We hope to be able to report lessons learned over the next two to three years as the Grizzly program is executed.

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