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When Systems are Simulations: T&E, VV&A, or Both?

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This paper addresses the use of modeling and simulation (M&S) and the importance of its credibility in supporting system acquisition. Focusing briefly on a previous work, "The Relationship of VV&A to T&E" (Allen et al. 1997), this examination does not address the specifics for performing VV&A, but instead reviews earlier work conducted to characterize M&S use in system acquisition. By introducing a new example of M&S application, this paper cites recently developed systems that are themselves simulations. As new acquisition systems, they require traditional test and evaluation (T&E). As simulations, they require verification, validation and accreditation (VV&A). Centering on key commonalities between these two processes, this examination focuses on a case study, describing how developers can meet T&E and VV&A requirements while lowering cost and reducing risk.

The primary purpose for both test and evaluation (T&E) and verification, validation and accreditation (VV&A) is risk reduction. Evaluating system performance against stated requirements fosters user confidence in the system produced. In system acquisition, M&S serves as a key tool in reducing time needed to field a system; in reducing resources needed to develop and evaluate that system; and in reducing decision risk. M&S also can provide a means to evaluate and improve quality, military utility and supportability of fielded systems.

In system acquisition's T&E phase, M&S is used to develop parameters for mission rehearsal; to design tests; to analyze data collected during testing; and to evaluate regions of the operational envelope not otherwise testable. While M&S is a useful tool for predicting, training and planning, it is not a substitute for testing. M&S is practical only if it applies to the evaluation of the system being acquired, and only if it is capable of replicating reality to a required level. Evaluating M&S systems against the requirements, both system-specific and in terms of real-world representation, provides insight into M&S credibility.

Previous research

"The Relationship of VV&A to T&E" identified four cases in which M&S traditionally had been used to support system acquisition (*Table 1*). That research identified a clear overlap between the two processes and suggested areas where collaboration might reduce cost and risk. The paper's resulting dialog has promoted cooperation between the testing and VV&A communities.

In Case 1, M&S is built for reasons not related to system acquisition. Because no system is being acquired and no T&E activity is occurring, no defined relationship exists between T&E and VV&A for simulations and systems.

In Case 2, M&S is developed to support the concept exploration and program definition phases of acquisition. M&S precedes system development, but it is not updated as the system matures. The model loses congruence with the system under development. With the exception of requirements, any VV&A conducted will have little relevance to the mature system's T&E.

In Case 3, M&S supports a system under development. The system's digital representation precedes system development and is updated as the system matures. In this case, the real system and the model are separate, distinct entities. The model's VV&A and the system's T&E occur in parallel. Following the model-test-model paradigm, the T&E and VV&A processes complement and support one another. The model guides system development, and the developing system's test results refine the model.

In Case 4, the model is a system subset. M&S is totally embedded within the operational system. Integrating VV&A and T&E processes yields three benefits: commonality and reuse of testing tech-

niques; value of conceptual modeling; and early correction of system problems.

A new example

An addition to the previous case examples is Case 5, in which the system under test is itself a simulation. System hardware consists solely of the computer platform(s) required to run the simulation. The system software consists only of the simulation (*Table 2*).

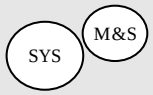
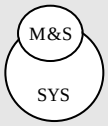
CASE	M&S	OPERATIONAL SYSTEM	RELATIONSHIP M&S to SYSTEM
1 No Acquisition	-Used for readiness, force structure, or sustainability -VV&A Plan	-No operational system developed -No TEMP	
2 Precedes Development	-Used for concept definition of operational system -VV&A Plan	-Normal acquisition -TEMP	
3 Supports Development	-Supports concept definition -Model updated during development & test -VV&A Plan	-Acq. supported & guided by M&S for perf. modeling & engineering trades -TEMP indirectly influenced by VVAP	
4 Part of Development	-M&S embedded in & developed as component(s) of operational system -VV&A Plan	-Normal acquisition -VVAP becomes part of TEMP effort -VV&A & DT&E/OT&E tests directly support each other	

Table 1. Relationship of VV&A and T&E processes

The relationship between the T&E and VV&A processes is roughly congruent. In earlier research, participants conducted a crosswalk of the two processes and then compared the information supporting each process (*Table 3*). They compared the VV&A plan format contained in the *Department of Defense (DoD) VV&A Recommended Practices Guide* to the Test and Evaluation Master Plan (TEMP) format. Researchers found the information requirements to be virtually identical. They also discovered that the VV&A process includes certain activities, such as code verification or algorithm validation, that are not necessarily part of the T&E process. However, where the T&E phase identified problems, it also unearthed the possible need to examine the code or algorithms. Hence, T&E can leverage significant VV&A processes.

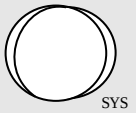
CASE	M&S	OPERATIONAL SYSTEM	RELATIONSHIP M&S to SYSTEM
5	M&S is the System	-Acquisition of M&S -Significant congruence between VV&A and T&E	

Table 2. Acquisition of a simulation

Key commonalities

Requirements

The T&E process is founded on requirements, including critical technical parameters, operational issues, and measures of performance and effectiveness. Maturity of the T&E process provides an excellent benchmark for the VV&A process to evolve. T&E assesses operational system performance in the same manner that VV&A assesses M&S credibility. The DoD Generic VV&A Process, described in the *Recommended Practices Guide*, identifies both the problem and the requirements for solving it.

The next step calls for determining the problem-solving approach. M&S is one problem-solving tool, but other tools also may be employed as well. Given that M&S will guide researchers to find at least part of the solution, the process identifies general requirements for model capabilities. Depending on the nature of these requirements, problem solvers may use an existing model either "as is" or modified, or they may need to develop a new model. Once researchers decide on an approach, they can establish requirements for the specific model(s) chosen and then prepare the model for use.

While the T&E process is rooted in requirements definition, the VV&A process has not yet learned the lesson or importance of requirements. Many programs attempt to avoid requirements definition or to make unfounded assumptions, one of which is that M&S is the correct tool to use when another tool might be more effective. Another example is choosing a specific model without adequate rationale.

Choosing an inappropriate model could lead to invalid results. This situation sometimes results from researchers' lack of familiarity with the VV&A process. However, instances have occurred in which participants intentionally have made sub-optimal decisions either to maximize other resources or to placate a decision maker who had already chosen a tool.

In some cases, researchers have tailored requirements from the VV&A process. Tailoring, a VV&A term, describes the action of focusing a well-planned VV&A effort on those tasks providing optimal return on investment. In this process, participants select V&V tasks and techniques that will render the most expedient, credible results by which to assess the model. Requirements definition, however, is not open to negotiation or tailoring. Common sense dictates that, to assess a simulation credibly, one must know what the simulation is supposed to accomplish!

Management

The T&E process is well-established and understood by a large community of developers, testers and

managers. By comparison, the VV&A process is relatively new. The T&E process employs mature methods that produce solid examples. VV&A would do well to emulate these methods. One example is the TEMP requirement delineating responsibilities for each testing community segment. Another example is the approval process for TEMP and other testing documents, which requires negotiation and compromise among participating organizations prior to the T&E effort.

By comparison, VV&A efforts reflect a wide variety of dissimilar and nonstandard approaches. Many of these approaches are incomplete, delaying the start of the VV&A process unnecessarily. Prior to beginning a VV&A effort, it is *essential* that participants identify roles and responsibilities (such as who will do what for whom, when, where, why and for how much). Unfortunately, many program managers do not learn this lesson until after they have expended time and money, and not until after they have lost the optimal window of opportunity during the simulation's development. VV&A's reputation as a costly discipline is compounded further by the fact that programs have had to exhaust valuable resources educating contractors, who already should understand how to implement VV&A.

Documentation

The T&E process is characterized by clearly defined documentation. Although researchers developed common VV&A reporting formats for DoD, many programs avoid committing implementation details into writing. Initial attempts at drafting a VV&A plan often include large tutorials written at considerable expense. Such treatises offer no new information, despite claims of "tailoring" to meet "unique" program needs.

However, the accuracy of such claims is limited. Where T&E spells out specific information requirements and criteria for assessing the test system, most VV&A plans to date have not provided executable detail needed to perform V&V. To ensure that stated tasks are necessary, researchers must identify specific V&V tasks and then link them to specific problem areas. Unfortunately, a combined lack of stated requirements and executable V&V detail results in VV&A plans that provide a high-level strategy with no clear direction and action.

Joint Warfare System case study

The Joint Warfare System (JWARS) program office initiated a V&V effort in October 1997 to support the production version of JWARS. Developed using an object-oriented software design approach, JWARS has been designed to become the next-generation theater warfare model. The Joint Requirements Oversight Council directed that a T&E plan be required as part of the Operational Requirements Document. T&E planning began in December 1997, using the V&V plan as its initial point of departure.

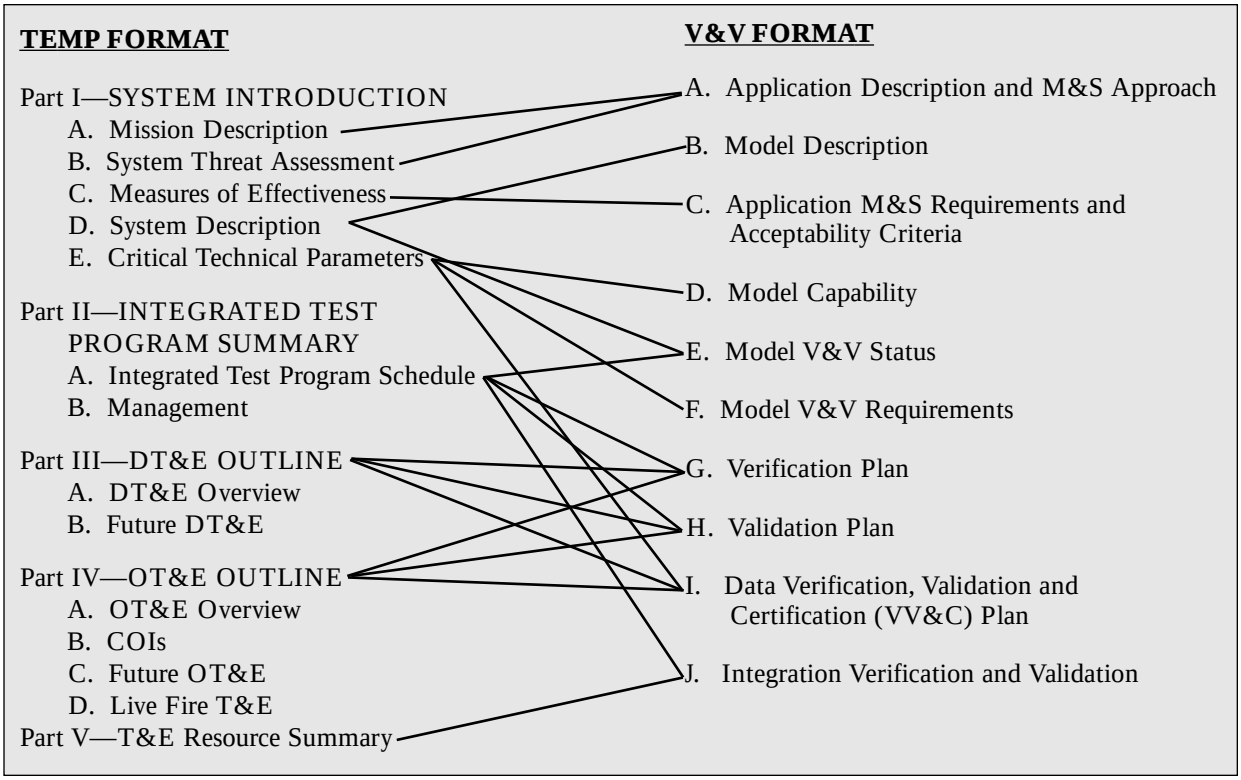


Table 3. TEMP, VV&A crosswalk

JWARS presents a new form of M&S use in DoD. Where M&S historically has been used to support weapons systems development and other tangible assets, the JWARS simulation is *itself* the system under test. As such, the system requires some form of T&E, while its formulation as a simulation requires that JWARS also undergo V&V, under DoD Instruction 5000.61. The relationship between these two processes has been the subject of research conducted in support of other DoD programs facing similar dilemmas. This research has been applied toward evolving an integrated JWARS T&E/V&V strategy.

The JWARS V&V effort is easily distinguishable from the developer's inhouse quality assurance. The effort is independent in that the V&V contractor reports to the Joint Analytic Modeling Improvement Program—the JWARS oversight body. Additional V&V performed beyond developer quality assurance demonstrates the program office's commitment to providing a useful and usable product to the warfare analysis community. During the first quarter of Fiscal Year 1998, the V&V contractor developed a plan using the Recommended Practices Guide as the primary resource. The V&V contractor also worked with an oversight group of recognized DoD VV&A experts, who provided input and direction. The V&V plan is currently under military service and unified commanders-in-chief review. Key reviewers have made favorable comments, but they also have expressed concerns regarding its supporting resources, calling attention to the V&V/T&E relationship.

JWARS is an acquisition category III program; therefore, per DoD acquisition directives, it does not require formal T&E. However, the JWARS Program Office elected to use the TEMP format to guide T&E plan development. T&E planning and execution run parallel to the V&V effort, leveraging from the V&V plan to ensure coordination between these two processes.

JWARS T&E versus traditional T&E

To support its T&E initiative, the JWARS program includes T&E from both the military services and from analytical agencies. These agencies traditionally support military T&E; however, agency operational test directors primarily are warfighters who test hardware (that is, platforms, weapons systems and equipment) that is distinctly different from analytical software such as JWARS. Whereas operational test directors represent hardware systems' military users, the *military analysts* are JWARS' targeted user community.

Military operators in the field often conduct hands-on weapons system operational testing. Similarly, operational test of a simulation calls for personnel trained and experienced in that arena. With JWARS, analysts are trained in theater-level simulation. Analysis agencies serve as test sites, and the operational test and evaluation agencies provide oversight and test reporting.

Another difference between traditional and JWARS T&E is JWARS' intended use of alpha and beta testing. Although tests are conducted at field sites and involve potential users, their primary purpose is to provide the developer with feedback. JWARS will use alpha and beta testing phases to support both the developer's quality assurance program and to provide the military community with an early opportunity to familiarize itself with the simulation.

The JWARS V&V plan identifies V&V techniques from the *Recommended Practices Guide*; however, limited resources have restricted problem domain validation to face validation by subject-matter experts. This technique, while necessary, is not sufficient for credibly validating a simulation of JWARS' magnitude. Therefore, the T&E effort focuses on *extending the validation envelope* through additional test techniques that meet both V&V and T&E objectives.

The MITRE Corporation, providing T&E/V&V program office support, has developed a crosswalk between the V&V plan and the TEMP. The crosswalk describes information overlaps existing between the two documents. It also identifies where existing V&V plan information could be leveraged to provide immediate input to the T&E plan. This approach saves time and money by reducing duplication of effort, while at the same time ensuring that these processes mesh and complement one another.

A working integrated process team develops strategy, identifies test activities and testers, ensures correct conduct and documentation of test events, reviews test results and provides recommendations to the Joint Analytic Modeling Improvement Program. The integrated process team comprises representatives from military analysis organizations and T&E agencies; the Office of the Secretary of Defense; the Joint Staff J-8 (force structure, resource and assessment directorate); and the JWARS program office. Advisors to the integrated process team includes the JWARS developer, as well as MITRE and Joint Data System representatives. For the integrated process team, an independent T&E contractor will prepare test plans for approval; provide periodic status briefings; coordinate required memoranda of agreement; and document T&E results.

In March 1998, researchers presented its initial concept for JWARS T&E to the process team. Prior to initial operational capacity, this concept focused on testing JWARS' planning and execution, as well as force assessment applications. For later testing, researchers also identified systems effectiveness and tradeoff analysis, as

well as concept and doctrine development and assessment. The concept also provided a set of proposed performance measures, highlighting traceability, utility and V&V as key performance parameters.

An additional briefing described the J-8 fielding plan, which describes logistic implementation for JWARS fielding at identified test sites. The fielding plan also designates the testing level at which each site would participate. The J-8 also provided a macro-level T&E process diagram enumerating various T&E tasks and responsibilities. Participants used this diagram to develop a strawman to partition lower-level tasks and to apportion those tasks among various players. These products are currently under review.

Prior to beginning either T&E and V&V, researchers must identify and agree upon roles and responsibilities. The roles played by traditional T&E agencies, analytical organizations and simulation users are key to JWARS testing. Similarly, a balanced perspective is needed among the military services in relation to the Office of the Secretary of Defense and the Joint Staff. While the integrated process team reflects a reasonable balance among these various players, significant issues remain unsolved regarding tests and test methods to be performed by each test site.

An issue researchers still must address is the relationship between the T&E effort and the V&V plan, which is only slightly more mature but still progressing. Despite this early positive direction, the V&V effort did not produce an executable plan of *specific* tasks and techniques. The T&E effort must, therefore, focus on specifying performance measures, critical technical parameters and critical operational issues. T&E also must concentrate on developing comprehensive, executable test plans that incorporate these elements.

The JWARS T&E schedule provides timeframes in which researchers must identify and assign tasks; determine task assessment criteria; negotiate test site support; and identify test events and resources. This schedule is both reasonable and necessary. Using the T&E community's proven methodology for planning a T&E effort is highly appropriate and is the most effective use of time and resources. The JWARS program office is committed to building a useful, usable simulation product for DoD, and it can achieve an optimal success level by participating with potential JWARS customers, military services and unified commanders-in-chief.

Conclusions

Simulation and system comparisons, along with the JWARS case study, highlight existing opportunities to leverage assets and resources. Coordinated efforts between the T&E and VV&A communities, conducted under a structure such as the working integrated process team, show the greatest potential for producing the optimum M&S product at less cost and risk.

Other DoD efforts can surely emulate the JWARS experience by blending the T&E community's acquisition knowledge with the M&S community's VV&A expertise. Although the JWARS effort is not complete, participants envision a highly credible final product produced at a reasonable cost. ❑

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