

T&E and V&V Integration

RPG Reference Document

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¹ This document replaces the 11/30/00 version. It contains a corrected hyperlink.

Background

Risk reduction is the primary purpose of both test and evaluation (T&E) and verification, validation, and accreditation (VV&A) [see special topic Risk Assessment and its Impact on VV&A]. By evaluating system performance against stated requirements, the user can gain confidence in the system produced [see special topic Requirements].

Test and Evaluation

The defense system acquisition process, as defined in *Department of Defense Regulation 5000.2-R*, governs the T&E of defense systems to assess the “feasibility of conceptual approaches, evaluate design risk, identify design alternatives, compare and analyze trade-offs, and estimate satisfaction of operational requirements” [Defense Systems Management College, *Test and Evaluation Management Guide*, August 1993]. The T&E process is a systems engineering-based approach that is initiated when a mission need is identified for a system. Exploration and definition of the system concept generate system requirements from which prototypes are developed to demonstrate the validity of the concept. The system proceeds through engineering and development, followed by full production and deployment.

T&E is composed of two primary phases: developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). DT&E is “concerned chiefly with attainment of engineering design goals” [Defense Systems Management College, *Test and Evaluation Management Guide*, August 1993], whereas OT&E focuses on the system’s operational effectiveness, suitability, and survivability. These processes are generally not serial, but occur simultaneously throughout the T&E process. DT&E is the primary focus during the early phases of concept exploration and demonstration, and OT&E takes the lead during the later phases of engineering, development, and deployment. In both DT&E and OT&E, the system’s requirements serve as a barometer against which test results are compared.

Modeling and Simulation

In the same manner that requirements are essential to the T&E process, requirements must also be defined for models and simulations. These requirements specify what the model or simulation must meet in its design or operation. Another similarity between the T&E process and the use of modeling and simulation (M&S) is the need to reduce risk. VV&A is the method by which risk can be reduced in the development and use of models and simulations. [See special topic Requirements for more information.]

Modeling and simulation (M&S) is also used to support the T&E process. In particular, M&S is a key tool in system acquisition for reducing the time to field a system, the resources needed to develop and evaluate that system, and overall decision risk. The use of M&S can also help evaluate and improve the quality, military utility, and

supportability of fielded systems. During T&E, M&S can be used to develop parameters for mission rehearsal, design tests, analyze data collected during testing, and evaluate regions of the operational envelope that are otherwise not testable. M&S is a useful tool for predicting, training, and planning, however, it is not a substitute for testing. M&S is only useful if it applies to the evaluation of the system being acquired, and if it can replicate reality to an acceptable level as required for the particular use.

Previous Research

Allen et al. [1997] identified four cases where M&S has traditionally been used to support system acquisition. That research illustrated that a clear overlap exists between the two processes and suggested areas where collaboration might reduce cost and risk. The dialogue created by that paper has served to promote cooperation between the testing and VV&A communities. The table below illustrates these four cases and a fifth case subsequently identified by Glasow and Borowski [1998]. A practical example of this relationship is provided in the [T&E / V&V Integration Checklist](#).

Relationship between V&V and T&E	
M&S	Operational System
Case 1: No Acquisition	
<ul style="list-style-type: none"> Used for readiness, force structure, or sustainability VV&A Plan 	<ul style="list-style-type: none"> No operational system developed No Test and Evaluation Master Plan (TEMP)
Case 2: Precedes Development	
<ul style="list-style-type: none"> Used for concept definition of operational system VV&A Plan 	<ul style="list-style-type: none"> Normal acquisition TEMP
Case 3: Supports Development	
<ul style="list-style-type: none"> Supports concept development Model updated during development and test VV&A Plan 	<ul style="list-style-type: none"> Acquisition supported & guided by M&S for performing modeling and engineering trades TEMP indirectly influenced by VV&A Plan
Case 4: Part of Development	
<ul style="list-style-type: none"> M&S embedded in and developed as component(s) of operational system VV&A Plan 	<ul style="list-style-type: none"> Normal acquisition VV&A Plan becomes part of TEMP effort VV&A and DT&E/ OT&E tests directly support each other
Case 5: System Under Test	
<ul style="list-style-type: none"> M&S is the system 	<ul style="list-style-type: none"> Acquisition of M&S V&V and T&E are congruent

Case 1. The model or simulation is built for reasons not related to system acquisition. Since there is no system being acquired and no T&E activity, there is no defined relationship between T&E and VV&A. Case 1 is, essentially, the null case.

Case 2. The model or simulation is developed to support the concept exploration and program definition phases of acquisition, specifically DT&E. Modeling and simulation precedes system development, but is not updated as the system matures. The model loses congruence with the system being developed. Except for common requirements of function, structure, and representation, any VV&A conducted would have little relevance to T&E of the mature system.

Case 3. The model or simulation supports a system under development. The digital representation of the system precedes system development and is updated as the system matures. In this case, the real system and the model are distinct entities. The VV&A of the model and the T&E of the system occur in parallel. Following the Model-Test-Model paradigm, the T&E and VV&A processes complement and support each other. The model is used to guide the system development, and the developing system's test results are used to refine the model. Case 3 applies to simulations used in both DT&E and OT&E.

Case 4. The model or simulation is a subset of the system and is totally embedded within the operational system. This integration of the VV&A and T&E processes yields three key benefits: commonality and reuse of testing techniques, value of conceptual modeling, and early correction of system problems. The reader is encouraged to read Allen, et al. [1997] for a full discussion of each of these benefits. Again, Case 4 applies to simulations used in both DT&E and OT&E.

Case 5. The system under test is itself a simulation. The system hardware consists solely of the computer platform(s) required to run the simulation. The system software consists only of the simulation.

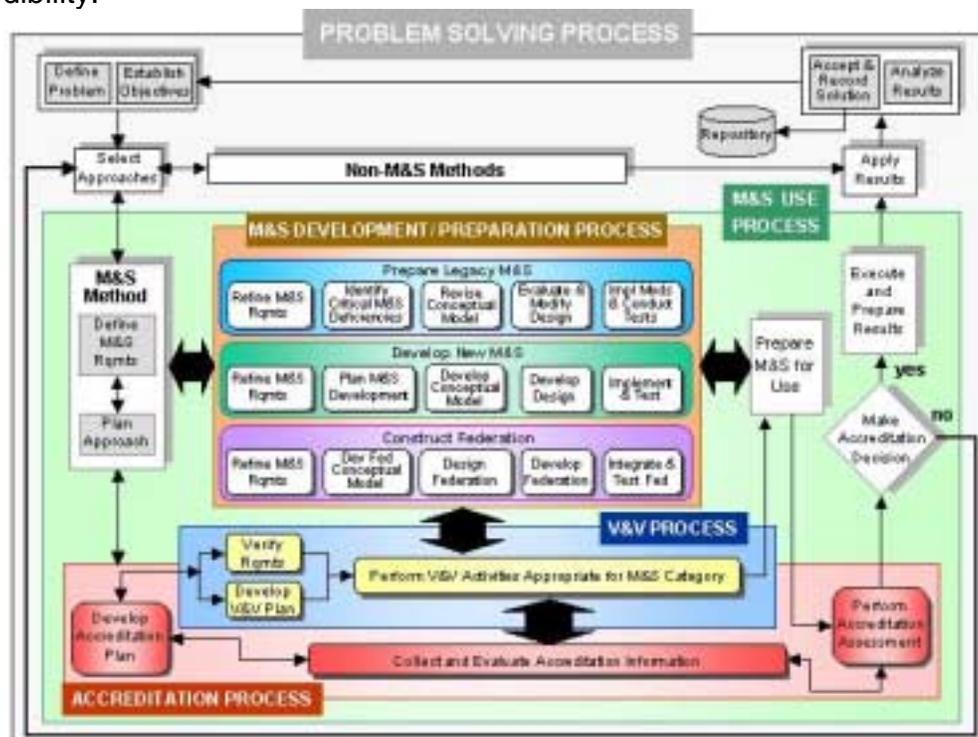
The relationship of the T&E and V&V processes in Case 5 is illustrated as being roughly congruent, with T&E a subset of V&V. However, a distinction is made in this case between V&V and VV&A. The four previous cases involved VV&A of the model or simulation because the model or simulation was distinct from the system under test and required accreditation for its intended use. In Case 5, however, the simulation and the system under test are synonymous. The milestone decision process associated with T&E is not an integral part of the T&E process, but occurs externally to T&E. In the same manner, the accreditation decision process is intentionally excluded from Case 5. The planning for both T&E and V&V activities should, however, recognize the information needs required to make the milestone and accreditation decisions, and produce the information that is necessary to both processes.

As part of the research conducted by Glasow and Borowski [1998], a crosswalk of the T&E and V&V processes was conducted and a comparison was made of the information required to support each process. The V&V and accreditation plan formats [see VV&A report templates] were compared to the Test and Evaluation Master Plan (TEMP) format, as defined in DoD Regulation 5000.2-R. The authors found that the information requirements were essentially identical, but that the VV&A process includes certain activities, such as code verification or algorithm validation, that are not part of the T&E process. However, where problems are identified during T&E, there may be a need to examine the code or algorithms, hence T&E is an open subset of the encompassing VV&A process. Ongoing case studies continue to examine this relationship to determine whether this characterization remains valid.

Key Commonalities

Requirements

The T&E process is founded in system performance requirements, including critical technical parameters, critical operational issues, key performance parameters (KPPs), and measures of performance and effectiveness. The maturity of this process provides an excellent benchmark for the evolution of the V&V process. In the same way that the T&E process assesses operational system performance, the V&V process assesses M&S credibility.



VV&A in the Problem Solving Process

The overall problem solving process begins by identifying the problem to be solved and the requirements for solving that problem. These early requirements are often functional or representational in nature. The next step is to determine the problem solving approach. M&S is one tool for problem solving, but other tools may also be used to arrive at a solution. Given that at least part of the solution will be obtained through M&S, functional and structural requirements for simulation capabilities are identified. Depending on these requirements, the problem solver may be able to use an existing model either “as is” or modified, or a new model may need to be developed. Once that decision is made, functional and representational requirements for the specific model(s) chosen are established and the simulation is prepared.

In the same manner that T&E is rooted in system performance requirements, the VV&A process also emphasizes clear and early requirements definition. Requirements definition is a difficult task, but necessary for any VV&A. Without clear requirements to state what the simulation is intended to do, it is virtually impossible to state whether it has been built to meet those requirements. In defining simulation requirements, it is important to ensure that M&S is indeed the correct tool to use for the given problem. The analyst must help the decision-maker decide whether another tool might be easier or less costly to solve the given problem. Clear requirements are also important to ensure that the simulation chosen was initially designed to answer the type of problem dictated by the problem at hand. The VV&A effort may need to be temporarily delayed until clear requirements have been determined. Although requirements definition takes time and effort, it ensures that the right simulation is built from the start and provides useful, credible information to help the decision-maker solve the problem. Requirements definition is often the first challenge that must be faced in conducting a VV&A effort.

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 uses mature methods that provide excellent examples that VV&A can emulate. For example, the TEMP requires that responsibilities for each segment of the testing community be delineated. Another example is the approval process for the TEMP and other testing documents, which requires negotiation and compromise among participating organizations prior to the start of a T&E effort. This process is delineated by acquisition policy. By comparison, VV&A efforts reflect a wide variety of dissimilar approaches. The lack of standardization in VV&A can make it very difficult for new users of a model to understand the previous VV&A efforts and benefit from those findings. However, similar to T&E, identifying roles and is essential before starting any VV&A effort. Programs that don't specify these roles and responsibilities in the beginning lose time and money in the long run. Hence, defining requirements and responsibilities are the two prerequisites to starting VV&A.

Documentation

The T&E process is also characterized by clearly defined documentation. Common reporting formats for VV&A have been developed for DoD and are consistent with the reporting requirements of the military services and the Joint Staff [see VV&A report templates]. It is important to commit implementation details to writing to document actions taken and decisions made, and to provide an historical account of the VV&A effort for future users of the simulation. However, avoid writing “tutorials” about VV&A or “rewriting” the RPG. For example, VV&A plans are executable documents and require specific details about the tasks and techniques that will be performed, the scheduling of these activities, and who will perform the techniques. Documents must include a clear action plan rather than merely offer high-level VV&A strategies that don’t outline how it will actually be done.

Integration of T&E and V&V in Practice: USMC JSIMS

A unique approach for integrating T&E and V&V is the U.S. Marine Corps’ (USMC) contribution to the Joint Simulation System (JSIMS). This integration is based on the expectation that operational testers will consider the assessment activities and results obtained from DT&E and V&V to determine the most efficacious use of OT&E resources. Early and continuous involvement by OT&E provides useful guidance to the developer, thereby supporting more cost-effective design changes and course corrections.

Although this effort is in the planning stage, an initial partitioning has been made to distribute the simulation/system requirements across the various assessment activities. The intent of this partitioning is to ensure that every requirement is assessed during at least one phase of T&E or V&V. Critical simulation/system requirements may be intentionally assessed during more than one phase. Partitioning requires that all assessors know when and how each requirement is to be assessed and by whom. The USMC JSIMS effort partitions the simulation/system requirements by phase of system development (initial and final operating capabilities). The specific test event under which each requirement will be assessed is also identified in the partitioning. The Requirements Partitioning Guidelines provided by Mihalow [1999] include examples that are repeated here to illustrate the type of partitioning approach used by USMC JSIMS.

Verification

The basic functionality of the simulation, its design, formats, and simple user interface responses are assessed during verification. The verification effort is used as the default partition, such that simulation/system requirements that are difficult to partition are assigned to the verification partition. Verification is the earliest assessment phase in the two processes. By placing these requirements in the verification partition, the analyst is given additional time to clarify the requirement and determine whether reassessment

during a later partition is appropriate. Examples of simulation/system requirements that are assessed during verification are counting and binary choice requirements:

- JSIMS shall maintain a record of the number of times an item is attacked by air or by artillery.
- JSIMS shall destroy cargo and cargo contents if the transport is destroyed.

Validation

Requirements involving comparisons to the real world and that determine the simulation's accuracy are addressed through validation. The real world includes doctrine and existing system data. Examples of simulation/system requirements that are validated include the following:

- JSIMS shall provide the use of actual opposing force Order of Battle (OOB) data.
- JSIMS shall report damage to fixed-point targets from bomb/battle damage in a doctrinally correct manner.

DT&E

Developmental T&E considers the capacity, performance, and system interface requirements of the simulation.

- JSIMS shall support, in real time, a single or multiple exercise(s) containing the following: Obstacles/barriers (natural and man-made): threshold 200, objective 600.

OT&E

Operational T&E assesses JSIMS' capability from the USMC perspective, including the usability of user interfaces. Initial OT&E assesses the training capability of the simulation; subsequent OT&E may focus on future capabilities of JSIMS, including planning, mission rehearsal, and course of action analysis.

- JSIMS must support staff training at CINC, JTF, and MARFOR levels (threshold).
- JSIMS shall reduce the number of support personnel required to conduct a given exercise: 33 percent (threshold), 66 percent (objective).

Axioms and Challenges of the USMC JSIMS Method

This initial parsing of simulation/system requirements and their assignment to specific assessment activities emphasizes three fundamental axioms. First, assessment activities, whether T&E or V&V in nature, should be done at the earliest point in the simulation development process to minimize the costs of reengineering. Second, neither T&E nor V&V can be a 100% level of effort, but represents a heuristic, 80% solution to simulation assessment. Third, the T&E and V&V processes should run in parallel and offer methods and results that the other process can leverage.

Among the difficulties reported in this partitioning approach is the recognition that some simulation/system requirements do not fall neatly into the given categories. The heuristic employed is to assess such requirements as early as possible in the simulation development lifecycle. For example, if it is uncertain whether a requirement should be assessed during DT&E or OT&E, a choice is made to assess it during DT&E. Should the results of the DT&E assessment be insufficient, additional assessment can then be made during subsequent OT&E.

As found in the USMC JSIMS case study, OT&E personnel require access to DT&E and V&V activities and results in order to leverage off these activities and findings to support OT&E events. OT&E may accept the findings of earlier assessments, suggest test changes for future assessments, or elect to reassess requirements that are deemed insufficiently tested.

Conclusion

The theoretical constructs discussed in this document illustrate the congruence between T&E and V&V. This congruence supports the premise of increased coordination and complementary leveraging of resources, schedules, methods, and results. Both processes foster risk reduction and can contribute significantly to the development and fielding of usable and useful simulation tools within DoD at reduced cost and risk.

The USMC JSIMS example illustrates how the T&E and M&S communities can collaboratively work to achieve these common goals. Although this effort is ongoing, it is envisioned that the final products of USMC JSIMS will prove to be highly credible and produced at a reasonable cost. It is important, however, to recognize that this program is breaking new ground and should be lauded for the conscientious efforts being made to meet both sets of policy requirements (T&E and V&V), while focusing on top-quality simulation products for DoD.

References

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RPG References in this Document:

- select menu: *RPG Diagrams*, select item: "VV&A in the Overall Problem Solving Process"
- select menu: *RPG Reference Documents*, select item: "T&E / V&V Integration Checklist"
- select menu: *RPG Special Topics*, select item: "Requirements"
- select menu: *RPG Special Topics*, select item: "Risk and Its Impact on VV&A"
- select menu: *RPG Templates*, select item: "VV&A Report Templates"

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