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Test and Evaluation
MODELING AND SIMULATION VERIFICATION, VALIDATION, AND ACCREDITATION METHODOLOGY

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CHAPTER 1

INTRODUCTION

1-1. PURPOSE.

a. The methodology described in this document will provide an integrated approach for the verification, validation, and accreditation (VV&A) processes required for the U.S. Army Developmental Test Command (DTC) Virtual Proving Ground (VPG) and the validation of customer models and simulations (M&S). The verification, validation, and certification (VV&C) of data is treated as a subordinate activity required for an application-specific accreditation.

b. The guidance contained in this document will supplement current Department of Defense (DOD) and Department of the Army (DA) guidance on M&S VV&A, specifically in areas that are weak in DOD Directive (DODD) 5000.59, AR 5-11, and DA Pamphlet 5-11. Current DOD M&S VV&A guidance predominately addresses issues associated with software solutions to M&S and does not address other implementations of M&S such as hardware-in-the-loop and physical models which are common in the T&E community. In addition, the DOD M&S VV&A community uses terminology that is more appropriate for wargame simulations and training simulators. DTC requires terminology geared toward M&S applied to acquisition and testing. This document addresses these shortcomings and provides a VV&A methodology tailored for DTC needs.

1-2. REFERENCES. Required and related publications are listed at appendix A.

1-3. BACKGROUND.

a. Per DODD 5000.1, M&S shall be used to reduce time, resources, and risk in the acquisition process and to increase the quality of the system being acquired. Representations of proposed systems shall be embedded in realistic, synthetic environments to support the various phases of the acquisition process. DTC initiated the VPG program to reengineer the Army's test capability in support of acquisition streamlining. The VPG provides a comprehensive interrelated set of stimuli and synthetic environments which will confirm a system's readiness and technical maturity, from concept through fielding. These stimuli and synthetic environments are subject to VV&A to ensure that the test data gathered are reliable and valid. In November 1995, the DTC VV&A Working Group was chartered to study VV&A requirements and develop an appropriate VV&A process for application to developmental testing. The working group was chaired by Redstone Technical Test Center until November 1996 when the group transitioned to a review committee. HQ DTC chairs the VV&A Review Committee. In June 1996, a Process and Procedures subgroup was formed. This subgroup, which has been responsible for the development and maintenance of this methodology, is chaired by the Yuma Proving Ground.

b. To date, we have identified several VPG efforts as pilot projects to undergo VV&A according to the methodology. The objective is to determine the adequacy of the methodology. The methodology will be updated annually to reflect lessons learned from implementing these pilot projects. The selected projects are the Global Positioning System Model, Comanche Flight Test Simulation Station, Dynamic Infrared Scene Projector, Virtual Range, 4-D Weather Model,

and Weapons Performance Model. Other VPG projects that are undergoing VV&A are the Advanced Distributed Electronic Warfare Simulator and the Simulation/Test Acceptance Facility.

1-4. SCOPE.

a. This pamphlet provides a comprehensive guide for Headquarters, DTC, and its test center personnel involved in the VV&A of M&S.

b. VV&A guidance contained herein is broadly applicable to all VPG components, interfaces, and data. Additionally, this methodology may be applied to the validation of customer M&S. This document is composed of the following:

Chapter 1: This introductory section.
Chapter 2: Discussion of M&S system development and VV&A process.
Chapter 3: Explanation of how to choose, plan, and implement V&V tasks.
Chapter 4: Discussion of accreditation.
Chapter 5: Discussion of the role of the VV&A Review Committee.
Appendix A: A list of reference documents cited in this pamphlet.
Appendix B: Discussion of each verification task.
Appendix C: Discussion of each validation task.
Appendix D: Discussion of each data V&V task in detail.
Appendix E: Discussion of the V&V Implementation Plan contents.
Appendix F: Discussion of the V&V Report contents.
Appendix G: Discussion of the Accreditation Plan contents.
Appendix H: Discussion of the Accreditation Report contents.
Appendix I: An acronym list and a glossary.

CHAPTER 2

VERIFICATION AND VALIDATION (V&V) AND MODELING AND SIMULATION (M&S) SYSTEM DEVELOPMENT

2-1. GENERAL.

a. AR 5-11 mandates VV&A of Army M&S Management Program systems during the developmental process. Verification & validation must be accomplished as early as possible in the process. Finding and resolving problems early in the developmental cycle will reduce program risk as well as reduce test design, development, and testing costs. Verification can be used to detect the faults, and validation can be used to reduce surprises. This VV&A methodology must be tailored to the specific characteristics of the developmental program. The developmental program must, however, provide adequate documentation and configuration management of requirements, design, test plans, and test cases at all levels of development. The V&V guidance presented in this document is intended to be broadly applicable to any M&S developmental process, regardless of specific feedback or iteration requirements. Cost associated with VV&A is typically 10-15 percent of the developmental cost. However, the estimate depends on the level of verification and validation.

b. Figure 2-1 shows the conceptual relationship of V&V steps to the various developmental products. As shown, each verification activity checks the relationship between two of the developmental products to ensure correct transformation of specifications from predecessor to successor developmental products. Validation activities evaluate the product as a whole, comparing it with the “real world.” Validation does not specifically address transformation issues.

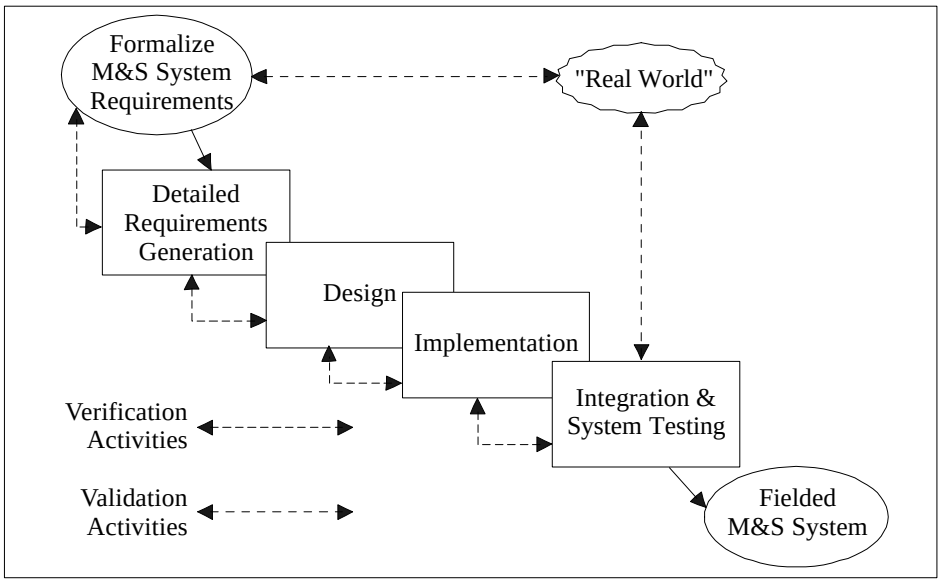

Figure 2-1. The Relationship of V&V Activities to M&S Development

2-2. MODELING AND SIMULATION.

a. A *model* is a physical, mathematical, or otherwise logical representation of a real system, entity, phenomenon, or process (DOD 5000.59-P). A model must describe the real system in enough detail to provide valid predictions of the behavior of the real system. Figure 2-2 shows the concept of a model. The parameters of a model correspond with characteristics or attributes of the real system. Input to a model corresponds with identified real system input. Output from a model allows inference about the performance or behavior of the real system. Models are either physical or abstract. Physical models could include globes, wind tunnels, and flight simulators. Abstract models could include chemical formulae, circuit diagrams, flow charts, mathematical equations, and budgets (reference "Simulation with GPSS and GPSSV").

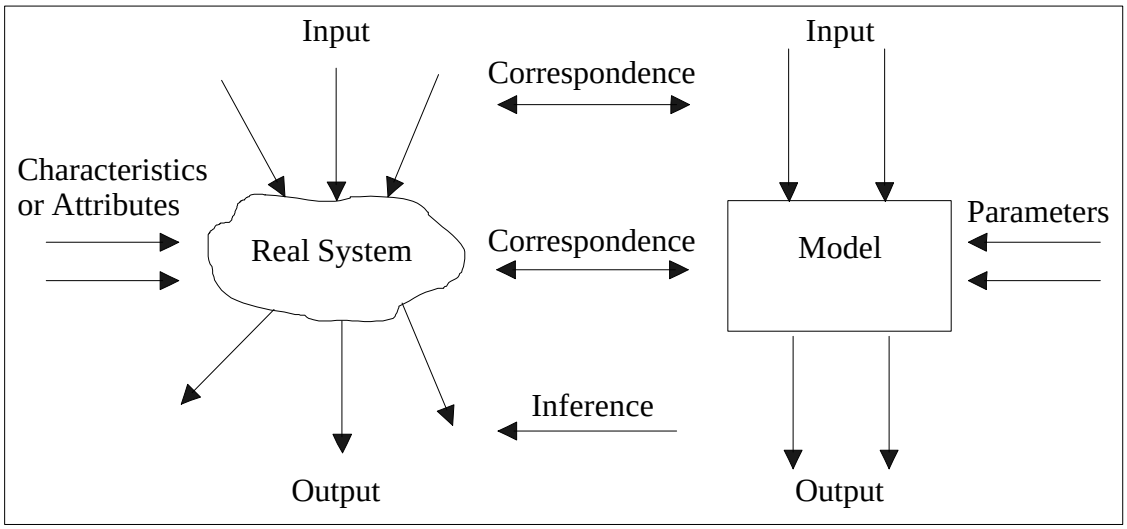

Figure 2-2. Concept of a Model

b. A *simulation* is the implementation of a model over time (DOD 5000.59-P). It is the operation or exercise of a model of a real system in order to study the behavior of that system without disrupting the entire real system or its environment. Experiments that would be too inconvenient, expensive, and time consuming to do on a real system could be done with models. To avoid disrupting an entire real system and its environment, experiments can also be done with components of the real system by interfacing the components with a simulation.

c. *VPG M&S* include: synthetic environments, virtual instrumentation, databases, and stimulators. The synthetic environment simulates the test ranges, facilities, background, and conditions in which the system under test (SUT) will operate. Virtual instrumentation simulates the test instrumentation and interfaces with a SUT model. Databases allow time-synchronized simulations capable of replaying real/synthetic comparisons and allow the conduct of failure analysis and simulation validations. Synthetic stimuli simulate the signals (targets, signatures, network messages, etc.) to a sensing device and interfaces with a real item-under-test to incite it to perform a function (for example, hardware-in-the-loop (HWIL) simulations).

d. The s*ponsoring agent* is the agency that sponsors the development or use of M&S utilizing either in-house, other government agency, or contract resources (AR 5-11).

For VPG M&S, the sponsoring agent will typically be a DTC test center. For customer M&S, the sponsoring agent will typically be an engineering or technical user or the program manager.

e. The *developing agent* is the agency that actually develops an M&S. The developing agency and the sponsoring agency may be the same (AR 5-11).

f. A *configuration item (CI)*, as described in MIL-STD-973, is an aggregation of hardware, software, or both that satisfies an end use function and is designated for separate configuration management. A system engineering development is made up of one or more CIs. CIs are selected based on tradeoffs among function, size, criticality, interface considerations, the need to be separately documented and controlled, and other factors.

g. An M&S system may be composed of any combination of hardware and/or software CIs and there are standards that cover their development. See Table 2-1 for a list of some of these standards.

Standard	**Title**
MIL-STD-499A	Engineering Management
MIL-STD-973	Configuration Management
MIL-STD-490A	Specification Practices
MIL-STD-498	Software Development and Documentation (IEEE Standard P1498/EIA IS 640 replaces MIL-STD-498)
IEEE 1278.1	Standards for Distributed Interactive Simulation (DIS) -- Applications Protocols
IEEE 1278.2	Standard for DIS -- Communication Services and Profiles
IEEE 1278.3	Recommended Practice for DIS -- Exercise Management and Feedback
IEEE 1278.4	Recommended Practice for DIS-- VV&A
IEEE 1278.5	Fidelity Taxonomy Standard for DIS

Table 2-1. Development Standards

h. An *interface* is the relationship between two CIs or between two systems. An interface is not hardware or software. Interfaces between DOD M&S systems are required to be compliant with High Level Architecture (HLA) standards. CI interfaces within an M&S system are not required to be HLA-compliant. HLA-compliancy enables the interoperability and reuse of models. HLA applications use federations of models and simulations which have been grouped together to solve a specific problem. Each individual M&S system of a federation requires VV&A, as does the federation as a whole. This methodology discusses the VV&A of the individual M&S. The VV&A of the federation must follow Institute of Electrical & Electronics Engineering (IEEE) Standard 1278.4 (Recommended Practice for Distributed Interactive Simulation (DIS)-VV&A). Security guidelines and regulations govern VV&A security issues.

i. Figure 2-3 summarizes the phases, reviews, baselines, and audits applied to system and CI development. This developmental process can be tailored to provide information for V&V within available resources. A development with only one CI may not have the system level activities. The beginning system level activities describe the requirements and design activities associated with the M&S system as a whole. Each CI is developed separately with its own documentation for requirements, design, fabrication/ coding, and testing. System integration tests examine the interfaces between two or more CIs. The system test tests the M&S system as a whole.

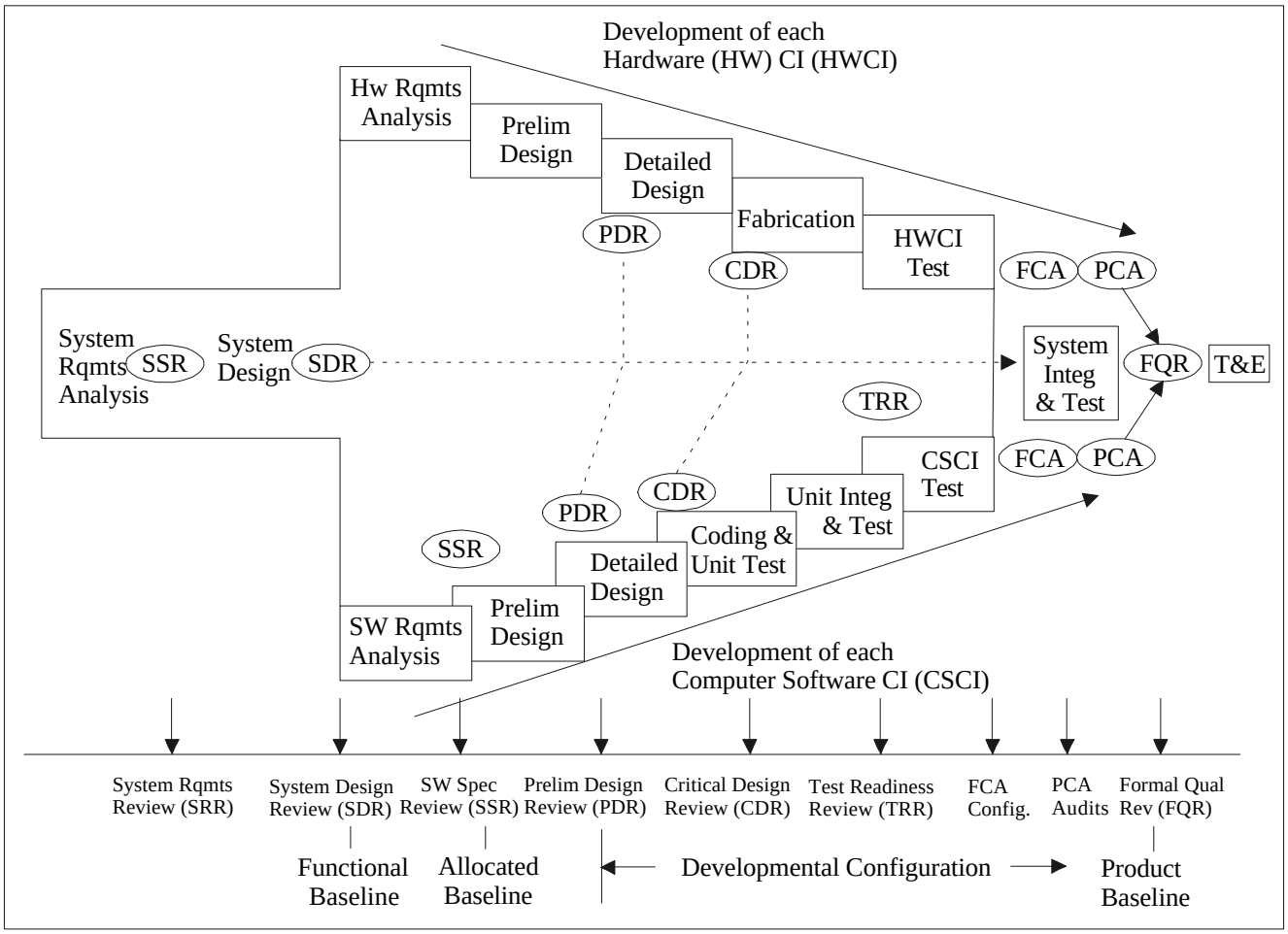

Figure 2-3. Hardware/Software Development

2-3. CONFIGURATION MANAGEMENT.

Configuration management (CM) is critical and integral to supporting VV&A activities, and is the responsibility of the developer. The CM process must be applied to all CIs. The goals of CM are to ensure integrity of the M&S by version control management, to record the history of the M&S, and to provide a means by which M&S users and application sponsors can request enhancements (DA Pamphlet 5-11). The CM process provides a consistent audit trail from the original M&S to the current version of the product. Effective CM procedures also prevent unauthorized modifications to the M&S that would invalidate previous VV&A efforts. In addition, if the M&S configuration is not properly managed, the credibility of that simulation can be jeopardized. Effective CM is essential to proper model use and to model accreditation. Attempting to accredit an M&S based on documentation that is several years out of date is difficult at best. Improper CM can result in a simulation losing or not attaining accreditation. Verification procedures for ensuring that proper CM takes place are discussed in appendix B (under task VE-6-2).

2-4. M&S V&V.

a. Figure 2-4 is an outline for the VV&A process. It applies to VPG tools that are developed to support testing.

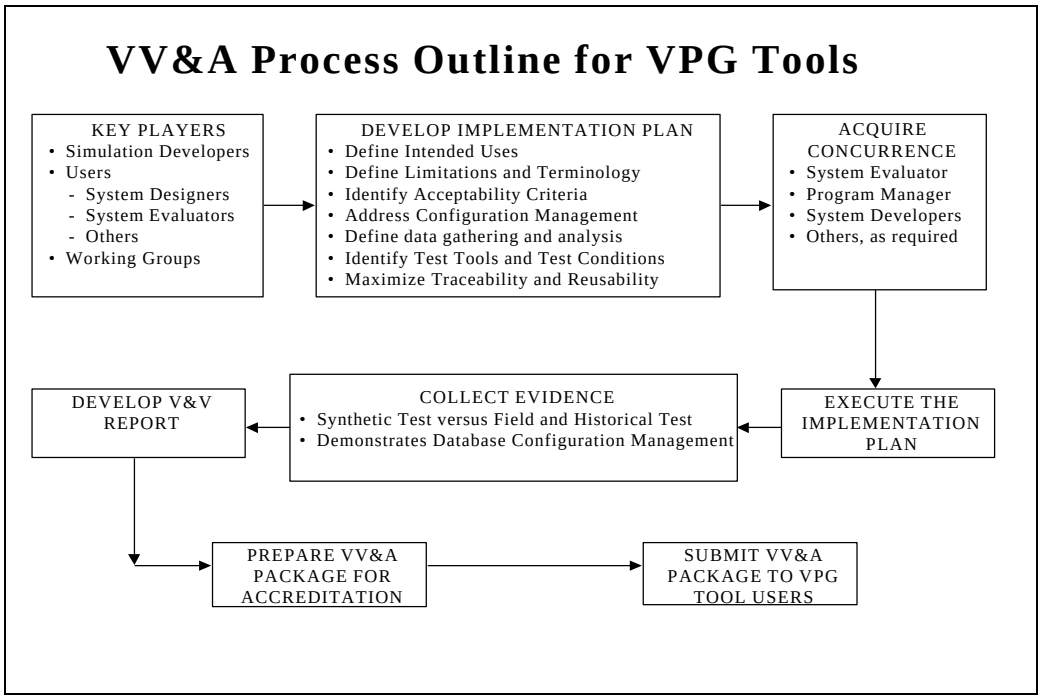

Figure 2-4. VV&A Process Outline

b. *Verification* is the process of determining if an M&S accurately represents the developer's conceptual description and specifications and meets the needs stated in the requirements document (AR 5-11). Ultimately, the verification process establishes if the simulation correctly performs the intended functions and the extent to which the simulation has been developed using sound system engineering. In VPG M&S, the verification of VPG interfaces is of particular importance to ensure that VPG M&S components are able to interact with each other and real SUT components. For example, virtual instrumentation interfaces with SUT models and analysis tools, SUT models interface with synthetic environments, and synthetic stimuli (e.g., HWIL simulations) interface with real SUT components.

c. *Validation* is the process of determining the extent to which an M&S accurately represents the real world from the perspective of the intended use of the M&S (AR 5-11). Validation has to do with the fidelity of the M&S. The *fidelity* of the M&S is judged by several factors, one of which is its ability to predict the known, or best estimate, of the behavior of the real system when subjected to the same stimuli. If the significant parameters of a real system have been properly incorporated into a model, a simulated experiment should reflect the behavior of a real system down to some level of detail commensurate with that description.

d. *V&V activities*, at a minimum, must meet the requirements of accreditation. V&V planning sessions must include representation from the accreditation authority and the developer. Corroborated V&V activities support accreditation decisions. Failure to adequately plan for accreditation needs may cause insufficient evidence to be gathered and require additional V&V work before accreditation can be achieved.

e. The *V&V agent* is responsible for ensuring the M&S is adequately verified and validated and for establishing a team to do the V&V. The V&V agent selects the V&V team members based on their background in methods and technologies which are pertinent to the model being assessed. They may also be selected due to access to the technical community or other relevant resources (reference "Simulation Validation, A Confidence Assessment Methodology"). For VPG M&S, the test center

sponsoring the development or use of the M&S is responsible for selecting a V&V agent. A DTC test center may be requested to perform validation of a customer model. The V&V team members for VPG M&S and customer models may come from resources that are in-house, from another test center, from another government agency (for example, the Post Deployment Software Support Agency, U.S. Army Training & Doctrine Command Analysis Center - White Sands Missile Range (TRAC-WSMR), or U.S. Army Materiel Systems Analysis Activity (AMSAA)), or contract resources.

f. The *V&V team* must keep the sponsoring agent informed of their activities. The developing agent provides the V&V team with plans and documentation used for specification of requirements, design, development, configuration management, etc. either directly to the V&V team or via the sponsoring agent.

g. The *VPG VV&A Review Committee* is responsible for this VPG VV&A methodology and overseeing its application. The V&V team must report its plans, reports, and schedules to this committee for approval or recommended changes. Chapter 5 details this process.

2-5. INDEPENDENT V&V.

To encourage objectivity and impartiality, the V&V team members should be as independent of the actual developers as possible. According to AR 5-11, an independent V&V agent should normally perform verification, but it remains the responsibility of the M&S proponent to ensure accomplishment. A test center doing in-house V&V of an M&S developed in-house should be avoided. When non-independent V&V is unavoidable, the V&V team should be established as a functionally independent sub-organization, to the greatest extent possible. For example, the V&V team members should not be the individuals who are developing the M&S. (Note this does not excuse designers or implementers from their responsibility of ensuring their own designs and code are verifiable.) The level of independence of the V&V team needs to be fully documented in the V&V organization descriptions contained in the V&V report, since this evidence lends credibility to the V&V results which will form the basis for an accreditation decision.

2-6. ACCREDITATION AND CERTIFICATION.

a. *Accreditation* is an official determination that an M&S system is acceptable for its intended purposes. It is based on experience and expert judgment and includes consideration of the extent to which V&V has been accomplished. Accreditation is a management level responsibility with assistance from the V&V team. The accreditation decision is based on the experience and expert advice provided by the V&V team. The specific use of the M&S must be considered in the context of its capabilities and limitations. Accreditation occurs at two levels: *Class of Applications* and *Application-specific*. While an M&S may be accredited for a Class of Applications, each specific application of that M&S also requires accreditation. If an M&S is being accredited for a single application but has not already been accredited for the class of application, it will essentially need to be accredited at both the Class of Applications and Application-specific levels at the same time (AR 5-11). These accreditation processes are discussed in chapter 4.

b. *Accreditation at the Class of Applications level* accredits an M&S for a generic set of purposes or applications and includes reviewing a complete audit trail of the development and use of the M&S. The audit trail includes reviews of M&S documentation, V&V documentation, configuration control, M&S assumptions, previous successful uses, and recognition of users'

acceptances (AR 5-11). The responsibility for M&S Class of Applications accreditation can vary depending upon the following three cases:

(1) For M&S that have one primary user, the user has accreditation responsibility;

(2) For M&S developed and used by a federally funded research and development center or a contractor, the M&S Army sponsor has accreditation authority;

(3) For M&S that affect the Army, that are not under Army control, and that are not used by the Army, the Army agency that is the proponent for the appropriate mission area, function, or activity normally has accreditation responsibility (AR 5-11).

c. *Accreditation* of *Application-specific level M&S* includes data certification, scenarios, and the qualification/training of the operator-analysts who will use the M&S (AR 5-11). For application-specific M&S, the application sponsor is the accrediting authority. The application-sponsoring agency reports its decisions to the class of accreditation proponent for that class of applications.

d. *Data Certification* is important to application-specific accreditation. The M&S data must be certified as verified and validated for each specific M&S usage. The M&S input data will be verified as correct, and validated as appropriate and reasonable for its usage. The certification process is discussed in chapter 4.

CHAPTER 3

VERIFICATION & VALIDATION IMPLEMENTATION

3-1. GENERAL.

a. V&V of an M&S system is an iterative process composed of the following steps:

(1) Gather information and perform a risk analysis.

(2) Identify V&V tasks.

(3) Write/update V&V Implementation Plan.

(4) Implement plan & report results.

b. First, the V&V team talks with the sponsoring, developing, and accreditation agents to gather information and to determine the risks associated with the intended use of the M&S, the accreditation requirements, and the M&S documentation. From this information, the V&V team determines what should be done and writes or updates the V&V Implementation Plan based upon the selected tasks. The membership of the V&V team may change as a result of writing/updating the implementation plan. As the implementation plan is executed, new information or risk areas may be uncovered that will require new research and new tasks to be included in the plan. The following paragraphs discuss these steps in more detail.

3-2. GATHER INFORMATION AND PERFORM A RISK ANALYSIS.

The first step in the V&V process, gathering information and performing a risk analysis, involves talking with the sponsoring, developing, and accreditation agents to:

a. Determine the intended use of the M&S from the sponsoring agent.

b. Determine the accreditation requirements from or in coordination with the accreditation agent.

c. Gather all available M&S documentation, including all information written about the model and, if applicable, the model from which it was or will be derived. This could include:

- Requirements
- Interface standards
- Developmental plans
- V&V plans
- Quality Assurance/Configuration Management Plans
- Design standards and specifications
- Coding/building standards
- Test plans, procedures, and results
- Data collection plan and procedures
- Data generation plan and procedures
- Data validation plan and procedures
- Internal security verification plans

- Problem reports/discrepancy report history
- Studies and analysis

d. Determine risk areas. The risk analysis involves reviewing developmental plans and past VV&A plans/results. For models already built, this information provides an assessment of the model's appropriateness for its intended use and provides information about areas the V&V team needs to further analyze due to lack of previous analysis or documented problems. For models to be developed, this information provides an assessment of critical areas that should be monitored. The V&V team should reassess risks periodically to determine if there are new risk areas that the team needs to monitor. Some risk areas to consider are:

- Supportability of the intended use
- Missing requirements documentation
- Adequacy of requirements
- Adaptation to various operational needs
- Safety
- Security and privacy
- Environmental conditions in which the M&S must operate
- Computer resources/utilization
- Design and construction constraints
- Personnel/human factors
- Logistics considerations
- Packaging requirements
- Quality of the M&S system
- Adequacy of Interface requirements, design, and implementation
- Missing design documentation
- Adequacy of design
- Missing test plans and test cases
- Adequacy of test plans and test cases
- Adequacy of the M&S system
- Compliance with standards
- Lack of adequate Configuration Management
- M&S developmental schedule
- M&S costs
- Test readiness
- Fidelity of the simulation
- Data

3-3. IDENTIFY V&V TASKS.

This section describes how to identify the specific V&V tasks the team should perform. These include tasks required to mitigate the risks identified by the risk analysis and the tasks required to meet the identified accreditation requirements.

a. Identify questions to ask. Before identifying the specific tasks to be performed, the V&V team should identify the questions to be answered based upon the type of model, the developmental stage of the model, and the risks identified. Since the questions that are important may change as the V&V effort progress, the V&V team should periodically reassess their objectives (i.e., what questions need to be answered).

(1) For verification, the V&V team needs to answer the following overall question: Does the M&S work as intended using sound system engineering techniques?

Additional specific questions are shown in figure 3-1 below. Questions VE-1 and VE-5 are appropriate for all verification efforts. If the intended use and/or requirements are not documented, the V&V team must either reengineer a requirements document or include the intended use and requirements they will evaluate in the V&V Implementation Plan. Although requirements and design documentation are recommended for all M&S, the documentation may be too expensive and too time consuming to reengineer for undocumented systems already developed and employed. When requirements documentation does exist, question VE-2 should be answered. If design documentation exists, questions VE-3 and VE-4 should be answered. Questions VE-6, VE-7, and VE-8 are more applicable to large or critical M&S developments where cost, schedule, and/or performance are very important factors.

Verification: Does the M&S work as intended using sound system engineering (SE) techniques?

√ VE-1: Is the intended use documented?
VE-2: Are the requirements complete, clear, testable, and consistent with each other?
VE-3: Is the design clear, correct, and consistent?
VE-4: Does the simulation conform to the documented design?
√ VE-5: Does the simulation conform to the documented requirements?
VE-6: Is the simulation being properly developed?
VE-7: How much has the simulation been tested and how free of problems is it?
VE-8: Is the simulation on schedule and cost as planned?

Figure 3-1. Verification Questions

(2) For validation, the V&V team needs to answer the following overall question: Is the M&S realistic from the perspective of its intended use? Additional specific questions are shown in figure 3-2, below. The first two questions are appropriate for all verification efforts. If no requirements documentation exists, the V&V team should include the fidelity requirements they will evaluate in the V&V Implementation Plan. The last question may be appropriate for some M&S efforts.

Validation: Is the M&S realistic from the perspective of its intended use?

√ VA-1: Does the simulation requirements documentation require that the simulation represent the real world to an adequate degree of fidelity for the intended use?
√ VA-2: Simulation adequately tested for fidelity in representing the real world?

Figure 3-2. Validation Questions

(3) For data V&V, the V&V team needs to answer the following question: Are data utilized in the M&S appropriate and reasonable for its usage?

b. Identify tasks to answer questions. After the V&V team has determined what questions to answer, they can choose the appropriate tasks to be accomplished to answer those questions.

(1) Verification tasks. Figure 3-3 describes the tasks to be accomplished to answer the verification questions in figure 3-1. For each question the V&V team has chosen to answer, one or more tasks to answer that question should be selected. Appendix B describes each task in greater detail and provides guidelines for choosing among tasks.

√	**VE-1: Is the intended use documented?**
	VE-1-1: Review requirements documentation for description of intended use
√	VE-1-2: Document intended use
	VE-2: Are the requirements complete, clear, testable, and consistent with each other?
	VE-2-1: Review requirements for clearness, testability, and consistency
	VE-2-2: Verify traceability of lower and higher level requirements
	VE-2-3: Verify adequacy of system engineering requirements
	VE-2-4: Verify adequacy of quality requirements
	VE-2-5: Conduct interface analysis
	VE-2-6: Participate in requirements reviews
	VE-3: Is the design clear, correct, and consistent?
	VE-3-1: Review design documentation
	VE-3-2: Verify traceability of design and requirements
	VE-3-3: Participate in design reviews
	VE-3-4: Participate in design walk-throughs/inspections
	Examine Program Design Language (PDL) for complexity -- See VE-6-4
	VE-4: Does the simulation conform to the documented design?
	VE-4-1: Verify traceability of design to test cases
	VE-4-2: Witness tests to ensure design functions are tested
	VE-4-3: Test design conformance
	VE-4-4: Participate in code walk-throughs/inspections
	VE-5: Does the simulation conform to the documented requirements?
	VE-5-1: Verify traceability of requirements to test cases
	VE-5-2: Conduct/witness acceptance test
	VE-5-3: Prepare breadth of testing metric report (% requirements tested and % requirements passed)
	VE-6: Is the simulation being properly developed?
	VE-6-1: Conduct compliance testing
	VE-6-2: Review Configuration Management Procedures
	VE-6-3: Conduct/Witness Configuration Audits
	VE-6-4: Complexity metrics report
	VE-7: How much has the simulation been tested?
	VE-7-1: Prepare depth of testing metric report (% tested and passed testing)
	VE-7-2: Prepare fault profiles report (open versus closed anomalies)
	VE-7-3: Prepare reliability metric report (Mean time between failures)
	VE-8: Is the simulation on schedule and cost as planned?
	VE-8-1: Prepare cost metric report
	VE-8-2: Prepare schedule metric report
	VE-8-3: Prepare computer resource utilization metric report
	VE-8-4: Prepare manpower metric report
	VE-8-5: Prepare developmental progress metric report
	VE-8-6: Prepare requirements stability metric report
	VE-8-7: Prepare design stability metric report
	VE-8-8: Participate in test readiness review

Figure 3-3. Verification Tasks

(2) Validation tasks. Figure 3-4 describes the tasks to be accomplished to answer the validation questions in figure 3-2. The V&V team should choose one or more tasks to answer each question. Appendix C describes each task in more detail.

√	**VA-1: Does the simulation requirements documentation require that the simulation represent the real world to an adequate degree of fidelity for the intended use?**
	VA-1-1: Review requirements documentation for adequate model fidelity requirements
√	VA-1-2: Document evaluation criteria for model fidelity
√	**VA-2: Simulation adequately tested for fidelity in representing the real world?**
	VA-2-1: Review developer's test plans to ensure model fidelity
	VA-2-2: Witness developer's test(s) to ensure model fidelity
	VA-2-3: Ask experts to differentiate between model and real world data flow, controls, and outputs (i.e., Turing Test)
	VA-2-4: Model-Test-Model - Use T&E results in an iterative method of successive model improvements until validated to the desired degree
	VA-2-5: Graphically compare model variables with real world variables
	VA-2-6: Compare animation/graphics playback of simulation with real world
	VA-2-7: Compare model with other M&S that has already been accredited
	VA-2-8: Conduct Face Validation - Use estimates and intuition of experts to compare model and real world behaviors subjectively
	VA-2-9: Validate simulation using functional decomposition - Validate the simulation's functional components and then validate how well the components fit together
	VA-2-10: Predictive validation - Compare past output data with the observed simulation output data generated from past input data

Figure 3-4 Validation Tasks

(3) Data V&V. Figure 3-5 describes tasks required for answering the question for data V&V. Appendix D describes each task in more detail.

√	**D-1: Are data utilized in the simulation appropriate and reasonable for its usage?**
√	D-1-1: Verify Data - Review data used in the simulation to ensure that it has been formatted correctly, units of measure have values within the allowable range
√	D-1-2: Validate data - Compare data with corresponding known real world or best-estimate values to ensure data are appropriate and reasonable for its usage
	D-1-3: Conduct sensitivity analysis and/or stress tests

Figure 3-5 Data V&V

3-4. WRITE/UPDATE IMPLEMENTATION PLAN.

The V&V team should write a V&V Implementation Plan that describes the agreed-upon tasks the team will perform. Below is an outline for a V&V Implementation Plan based upon DA Pamphlet 5-11. Appendix E contains a detailed description of what the V&V team should include in each paragraph. When complete, the V&V Implementation Plan will be approved by the VPG VV&A Review Committee.

V&V Implementation Plan (Based upon DA Pamphlet 5-11)
1. Purpose. 2. Background. a. General M&S Description. b. Configuration Management Procedures. c. Identification of Agencies. 3. V&V Responsibilities. 4. Intended Uses of the M&S. 5. Information Sources. a. M&S Documentation. b. M&S Developers. c. Subject Matter Experts (SMEs). d. Validation Data. e. Previous V&V. 6. Verification Plan. a. Methodology. b. Tasks and Milestones. c. Reporting Procedures. 7. Validation Plan. a. Methodology. b. Evaluation Criteria. c. Tasks and Milestones. d. Reporting Procedures. Appendices.

Figure 3-6. V&V Implementation Plan

3-5. IMPLEMENTATION PLAN & REPORT RESULTS.

The V&V implementation tasks can be broken into the following five major areas:

- Documentation
- Reviews/Walk-Throughs/Inspections/Audits
- Metrics
- Testing
- Data V&V

A report containing the results of this analysis should be provided to the accreditation agent. If the V&V team is doing V&V concurrently with the developmental effort, the V&V team should provide the developing and sponsoring agents interim reports that are timely enough that they can favorably impact the developmental effort.

a. Documentation.

(1) Documentation reviews and development. Documentation reviews involve analyzing documentation for format and general content. The tasks listed below cover document reviews for procedures, requirements, design, and test plans. Verification tasks (those that begin with “VE”) are described in appendix B, and validation tasks (those that begin with “VA”) are described in appendix C. The V&V team may also review other M&S documentation (such as user guides, operator manuals, and analyst guides) for clearness, correctness, consistency, and

completeness. If no requirements documentation exists, the V&V team will need to document the intended use and the evaluation criteria.

- Review Standard Procedures:
  VE-6-2: Review Configuration Management Procedures

- Review Requirements documentation:
  VE-1-1: Review requirements documentation for description of intended use
  VE-2-1: Review requirements for clearness, testability, and consistency
  VE-2-2: Verify traceability of lower and higher level requirements
  VE-2-3: Verify adequacy of system engineering requirements
  VE-2-4: Verify adequacy of quality requirements
  VE-2-5: Conduct Interface Analysis
  VA-1-1: Review requirements documentation for adequate model fidelity requirements

- Document Intended Use and/or Evaluation Criteria:
  √ VE-1-2: Document intended use
  √ VA-1-2: Document evaluation criteria for model fidelity

- Review Design:
  VE-3-1: Review design documentation
  VE-3-2: Verify traceability of design and requirements

- Review Test Plans:
  VE-4-1: Verify traceability of design to test cases
  VE-5-1: Verify traceability of requirements to test cases
  VA-2-1: Ensure developer's test plan contains adequate tests for model fidelity

(2) Reporting results of documentation reviews. The V&V team should include all results of the documentation reviews in the final V&V report provided to the accreditation agent.

(3) If the V&V team is doing the documentation reviews concurrently with the development of the M&S, the V&V team should provide timely reports to the sponsoring and developing agents. The report should contain a list of recommended changes along with a rationale for making the changes. The developing agent should evaluate each recommended change and should either make the change or reply as to why the change should not be made. This should be a cooperative effort with the goal of gaining an understanding of what the developer is planning to do and ensuring that the planned product will be suitable for its intended use.

b. Reviews/walk-throughs/inspections/audits. The following tasks involve reviews, walk-throughs, inspections, and audits. These tasks involve face-to-face communication between the developer and the V&V team. These tasks are most suitable for developmental efforts and should focus on gaining an overview of the developmental effort and/or detailed knowledge about specific high-risk areas. The goal is to understand what the developer is doing, planning to do, and ensuring the planned product will be suitable for its intended use. The V&V team should discuss any concerns with the developer/sponsoring agent. Any unresolved concerns should be reported in writing.

VE-2-6: Participate in requirements reviews
VE-3-3: Participate in design reviews

VE-3-4: Participate in design walk-throughs/inspections
VE-4-4: Participate in code walk-throughs/inspections
VE-6-3: Conduct/Witness Configuration Audits
VE-8-8: Participate in test readiness review

c. Software Metrics.

(1) Metrics enable the V&V team to quantitatively track cost, schedule, and performance of the developmental effort. Metrics are most applicable to large and/or critical software developmental efforts. DOD 5000.2-R requires software metrics to be used on all acquisition category (ACAT) I, IA, and DOD oversight systems. The cost, schedule, requirements traceability, and fault profile metrics adequately support these reporting requirements. DOD policy also requires those systems to demonstrate, prior to entering dedicated operation of testing, that requirements and design are stable and that adequate and sufficient testing of software and interfaces has occurred. The requirements stability, design stability, depth of testing, and breadth of testing metrics can serve this purpose (DA Pamphlet 73-7).

(2) It is important to note that metrics only provide indications of potential problems arising during the software development. They provide the V&V team with a tool for pinpointing potential risk areas that need further investigation. Metrics should be graphed over time so the V&V team can see trends that indicate potential problem areas, as well as areas that indicate improvements. Metric tasks described in appendix D are listed below:

- Management Metrics:
  VE-8-1: Prepare cost metric report
  VE-8-2: Prepare schedule metric report
  VE-8-3: Prepare computer resource utilization metric report
  VE-8-4: Prepare manpower metric report
  VE-8-5: Prepare developmental progress metric report

- Requirements Metrics:
  Requirements Traceability (VE-2-2, VE-3-2, VE-4-1, and VE-5-1)
  VE-8-6: Prepare requirements stability metric report

- Quality Metrics:
  VE-5-3: Prepare breadth of testing metric report (% requirements tested and % requirements passed)
  VE-6-4: Complexity metrics report
  VE-7-1: Prepare depth of testing metric report (% tested and passed testing)
  VE-7-2: Prepare fault profiles report (open versus closed anomalies)
  VE-7-3: Prepare reliability metric report (mean time between failures)
  VE-8-7: Prepare design stability metric report

d. Testing.

(1) The testing tasks the V&V team may perform include witnessing and/or performing verification tests and validation tests. Verification tests verify that the M&S meets its intended use. Validation tests validate that the M&S is realistic for its intended use. The V&V team should track the status of all noted problems and requested enhancements. The V&V team should write and/or review the test report for each test performed.

- Verification Testing (See appendix B for a more detailed description of these tasks.)
  VE-4-2: Witness tests to ensure design functions are tested
  VE-4-3: Test design conformance
  VE-5-2: Conduct/witness acceptance test
  VE-6-1: Conduct compliance testing

- Validation Testing (See appendix C for a more detailed description of these tasks.)

  VA-2-2: Witness developer's test(s) to ensure it contains adequate tests for model fidelity
  VA-2-3: Ask experts to differentiate between model and real world data flow, controls, and outputs (i.e., Turing Test)
  VA-2-4: Model-Test-Model - Use T&E results in an iterative method of successive model improvements until validated to the desired degree
  VA-2-5: Graphically compare model variables with real world variables
  VA-2-6: Compare animation/graphics playback of simulation with real world
  VA-2-7: Compare model with other M&S that has already been accredited
  VA-2-8: Conduct Face Validation - Use estimates and intuition of experts to compare model and real world behaviors subjectively
  VA-2-9: Validate simulation using functional decomposition - validate the simulation's functional components and then validate how well the components fit together
  VA-2-10: Predictive Validation

(2) The V&V team, in coordination with the developer, should assign a priority for each problem/change request (DA Pamphlet 73-7):

- Priority 1: Prevent the accomplishment of an essential capability. Jeopardize safety, security, or other requirements designated “critical.”

- Priority 2: Adversely affect the accomplishment of an operational or mission essential capability and no work-around solution is known. Adversely affect technical, cost, or schedule risks to the project or to life cycle support of the system, and no work-around solution is known.

- Priority 3: Adversely affect the accomplishment of an operational or mission essential capability, but a work-around solution is known. Adversely affect technical, cost, or schedule risks to the system or to life cycle support of the system, but a work-around solution is known.

- Priority 4: Result in user/operator inconvenience or annoyance, but does not affect a required operational or mission essential capability. Result in inconvenience or annoyance for development or support personnel, but does not prevent the accomplishment of those responsibilities.

- Priority 5: Any other effect.

e. Data V&V. Data V&V is needed for each specific use of a simulation that utilizes data. It is essential for an Application-specific level accreditation. Data V&V tasks include:

√ D-1-1: Verify Data - Review data used in the simulation to ensure it has been formatted correctly, units of measure have values within the allowable range.
√ D-1-2: Validate data - Compare data with corresponding known real world or best-estimate values to ensure data are appropriate and reasonable for its usage.
D-1-3: Conduct sensitivity analysis and/or stress tests.

f. V&V Report. The V&V team should write a V&V report that describes the results of all V&V activities. Figure 4-7 describes the outline for the V&V report. Appendix F contains a detailed description of what should be included in each paragraph. When complete, the V&V report needs to be approved by the VPG VV&A Review Committee.

V&V Report

1. Executive summary of V&V results
2. Overview of V&V Plan
3. Description of Verification Process and/or Tests
   a. Requirements Verification
   b. Design Verification
   c. Implementation Verification
   d. Developmental Process Review
   e. Unresolved Issues
4. Description of Validation Process and/or Tests
   a. Evaluation Criteria
   b. Validation Tasks
   c. Unresolved Issues
5. Planned V&V Activities
6. References/Attachments
7. Appendices

Figure 3-7. V&V Report

CHAPTER 4

ACCREDITATION

4-1. GENERAL.

a. Accreditation is the official determination that the M&S is suitable for its intended use and that the limitations of the M&S will not interfere with drawing the correct conclusions. Since M&S are abstractions, they approximate observed behavior rather than duplicate it. The accreditation process provides the procedures that the accreditation agent follows to make the accreditation decision. The accreditation process answers the question, "Will this M&S assist in examining issues and alternatives?" (DA Pamphlet 5-11).

b. Accreditation occurs at two levels: Class of Applications and Application-specific. Accreditation of a Class of Applications accredits the M&S for a generic set of purposes or applications. Given that an M&S is accredited for a Class of Applications, each specific instance of use for that M&S also requires accreditation, that is, an Applications Specific Level of accreditation (DA Pamphlet 5-11). If an M&S is being accredited for a single application but does not have a Class of Applications accreditation, it needs to be accredited at both Class of Applications and Application-specific levels simultaneously (AR 5-11).

4-2. ACCREDITATION PLANNING AND REPORTING.

The accreditation agent is responsible for and will prepare the accreditation plan and report with inputs from the V&V agent. The V&V agent does not prepare the accreditation plan or report, but ensures that the V&V activities are based on the accreditation requirements. However, the V&V agent is responsible for putting together the accreditation package and submitting that package to the accreditator. A sample accreditation plan and report are shown respectively in figures 4-1 and 4-2. Appendices F and G provide a more detailed description. When complete, the accreditation plan and report will be coordinated with the VPG VV&A Review Committee.

Accreditation Plan (DA Pamphlet 5-11)

1. Background.
2. Accreditation Responsibilities.
3. Schedules, Milestones, and Resources.
4. Intended Uses of the M&S.
5. Information Sources.
  a. M&S Documentation.
  b. M&S Developers.
  c. V&V Personnel/Agencies.
  d. Identify V&V Plan, Report, and Findings.
6. Acceptability Criteria.
7. Proposed Accreditation Methodology.

Figure 4-1. Accreditation Plan

Accreditation Report (Based on DA Pamphlet 5-11)
1. Executive Summary. a. Overall Issues and Findings. b. Strengths and Limitations. c. Identification of Agencies. d. Recommendation. 2. Acceptability Criteria.

Figure 4-2. Accreditation Report

4-3. CLASS OF APPLICATIONS LEVEL ACCREDITATION.

a. Class of Applications level accreditation accredits M&S for a generic set of purposes or applications. Some examples of generic uses of M&S include:

- Predicting system performance
- Assessment of design alternatives
- Determination of design alternatives
- Training
- Entertainment (for non-DOD purposes; some M&S technology from Simulation Network (SIMNET) has been exported to the commercial entertainment world, albeit the classified data have been modified)
- Stimulate other simulations or systems (hence, reuse)
- Testing of a system component or subsystem
- Emulation of a system component or subsystem
- Communication (drawings, images, pictures, descriptions, etc.)
- Control systems (fire control systems, navigation systems, autonomous or robotics vehicles)
- Reality augmentation and Heads-up Displays
- Engineering design
- Reliability assessment and prediction

b. The initial step of the Class of Applications level accreditation process is for the accreditation agent to establish acceptability criteria to fit the use of the M&S. There are two types of acceptability criteria: operational requirements and fidelity requirements. The operational requirements are “non-analytical” requirements that do not directly contribute to the resolution of program decisions. Operational requirements define hardware and software compatibility requirements, pre- and post-processing requirements for M&S, operations and training support requirements, etc. Fidelity requirements define how well required M&S functions must correspond to the “real world” in order for the M&S output to be considered acceptable for its intended use (reference Draft Simulation, Test, and Evaluation Process (STEP) Guidelines).

c. The next step is to review a complete audit trail of the development and use of the M&S. The audit trail includes review of M&S documentation, V&V documentation, configuration management procedures and records, M&S assumptions, previous

successful uses, and how well other users have accepted the M&S. The goal of this review is to determine the degree to which the M&S meet the established acceptability criteria.

d. The M&S class of applications accreditation responsibility can vary depending upon the following three cases:

(1) For M&S that have one primary user, the user has accreditation responsibility;

(2) For M&S developed and used by a federally funded research and development center or contractor, the Army sponsor for whom the M&S is developed has accreditation authority;

(3) For M&S that affect the Army, that are not under Army control, and that are not used by the Army, the Army agency that is the proponent for the appropriate mission area, function, or activity normally has accreditation responsibility (AR 5-11).

4-4. APPLICATION-SPECIFIC LEVEL ACCREDITATION.

a. Application-Specific level accreditation includes data certification, scenarios, and the qualifications/training of the operator/analysts who will use the M&S (AR 5-11). An Application-Specific level of accreditation is required for each specific instance of use (DA Pamphlet 5-11). For Application-Specific M&S, the application sponsor, is the accrediting authority. The sponsoring agency will accredit the M&S for a specific application after ensuring the M&S – as modified by the scenario, data inputs, or changes in operators/analysts – will provide results that responsive to the essential requirements of the intended use. The application sponsor prepares a brief report on the accreditation decision and forwards the report to the class accreditation proponent for that class of applications. Data VV&C is important to application-specific accreditation. The data used in the M&S must be certified as verified and validated for each specific M&S usage. The M&S input data will be verified to determine if the data to be used in the M&S are converted to the correct input formats and units of measure and have values within the allowable range as specified in the design of the M&S. For hardware M&S, this could include some of the following: checking the calibration of the instrumentation or sensors used in a test, verifying the processed data have been converted properly from the raw data, checking for clipped data, checking that meters and recorders are zeroed or nulled, and checking the functioning of data recorder trigger thresholds. The data will be validated to ensure the data utilized in the M&S are appropriate and reasonable for its usage. This involves comparing the data to corresponding known real world or best-estimate values.

b. Certified data can be obtained from approved data sources. Some of these approved sources are:

- AMSAA, for weapons effects data
- Topographic Engineering Center, for terrain data
- Deputy Chief of Staff for Intelligence, for threat data

If the M&S requires certified data from a data supplier, then the M&S user or application sponsor must request a new set of certified data for each application of the M&S. Data

items are normally certified for only a specific instance of application. Certified data items received from a data supplier must be verified again by the application sponsor to ensure the quality of the data.

4-5. RE-ACCREDITATION.

a. Class of Applications Level Re-accreditation. The M&S must be re-accredited for a new class of application, when a new version is released, or after a period of five years of active use since the last accreditation (or two years for threat data). The process of re-accreditation is identical to the initial accreditation process except that more information may be available. When a simulation is modified, changes may affect the simulation's suitability for particular applications. The changes must be compared against the user's intent (verification). The impact of the changes on simulation output must be compared against the real world system or process to measure the increase or decrease in fidelity (validation). In addition, when the real world changes, or the M&S is used for a different purpose, previous VV&A results should be reviewed to determine the impact on the simulation credibility. Since the real world rarely stays the same, it is useful to periodically review the VV&A status of an M&S to ensure consistency with the real world (reference draft STEP Guidelines).

b. Applications Specific level re-accreditation. A new application-specific accreditation is required after any changes to the scenario, database, or operator/analysts.

CHAPTER 5

VPG VV&A REVIEW COMMITTEE

5-1. RESPONSIBILITIES.

The responsibilities of the VV&A Review committee, according to the DTC VPG Master Plan, are:

- Develop, test, finalize, and maintain this VV&A Methodology.
- Oversee and approve application of the methodology to VPG developments and applications.
- Assess and report VPG progress.

5-2. MEMBERSHIP AND VOTING.

The VV&A Review Committee will consist of the following voting members: a representative from HQ DTC and one member from each test center: Aberdeen Test Center, Aviation Technical Test Center, Dugway Proving Ground, Redstone Technical Test Center, Electronic Proving Ground, White Sands Missile Range, and Yuma Proving Ground. Approval by the HQ DTC representative and at least 5 review committee voting members will constitute approval by the VPG VV&A Review Committee.

5-3. REVIEW PROCESS.

a. All DTC M&S/VPG VV&A efforts must follow this methodology. Any changes to the methodology will require approval of the VV&A Review Committee.

b. The V&V team for each DTCVPG VV&A effort will submit its plans, reports, and schedules to the VV&A Review Committee. The committee will review the VV&A plans and reports to determine if the methodology has been followed, to determine the adequacy of the plans and reports, and will recommend improvements, if required. The VV&A Review Committee will grant approval, grant conditional approval, or require the plan or report to be rewritten.

APPENDIX A

REFERENCES

Section I
Required Publications

AR 5-11
Management, Army Model and Simulation Management Program

DA Pamphlet 5-11
Management, Verification, Validation, and Accreditation of Army Models and Simulations
(URL: http://www.amso.army.mil/pam5-11/index.htm)

DoD 5000.59-P
Modeling and Simulation (M&S) Master Plan (DRAFT)
(URL: http://www.amso.army.mil/mstrpln/index.htm or
http://www.dmso.mil/docslib/mspolicy/msmp/1095msmp/)

MIL-STD-973
Configuration Management

MIL-STD-498
Military Standard Software Development and Documentation
(URL: http://www.isti.disa.mil/cfs/std498.html)

Section II
Related Publications

AR 73-1
Test and Evaluation Policy

DA Pamphlet 73-4
Developmental Test and Evaluation Guidelines

DODD 5000.1
Defense Acquisition

DOD 5000.2-R
Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs

"Simulation with GPSS and GPSSV," P.A. Bobillier, B.C. Kahan, A.R. Probst,
Prentice-Hall, Inc. Englewood Cliffs, New Jersey

"GLOSSARY OF MODELING AND SIMULATION (M&S) TERMS" (DRAFT),
Headquarters Department of Defense, Washington, D. C., 29 August 1995
URL: http://www.dmso.mil/docslib/mspolicy/glossary/glossary.html

"Introduction to Operations Research," Hiller & Lieberman, 1986, Holden-Day Inc., Oakland, CA

"System Engineering Management Guide," January 1990, Defense Systems Management College, Ft. Belvoir, VA

"Software Management Guide," April 1992, Software Technology Support Center, Hill AFB, UT

"Department of Defense Verification, Validation and Accreditation (VV&A) Recommended Practices Guide," November 1996, Office of the Director of Research and Engineering Defense Modeling and Simulation Office
(URL: http://www.dmso.mil/docslib/mspolicy/vva/rpg/)

"Simulation Validation, A Confidence Assessment Methodology," 1993, Peter L. Knepell, Deborah C. Arangno, IEEE Computer Society Press, Los Alamitos, CA

"Pre-Publication Copy, Department of the Army Pamphlet 73-7, Test and Evaluation, Software Test and Evaluation Guidelines," Headquarters Department of the Army, Washington, DC, 31 July 1996.
(URL: http://www.army.mil/swmetrics/pam.htm)

Draft Simulation, Test, and Evaluation Process (STEP) Guidelines, December Headquarters Department of Defense, Washington, D. C., 29 August 1995

NOTE: DOD-related VV&A information can be accessed on the World Wide Web (www) through the Defense Modeling and Simulation Office home page at URL http://www.dmso.mil. Links from this URL to other DOD and Service-level web sites make this an excellent starting point for locating DOD VV&A information on the web.

APPENDIX B

DESCRIPTION OF VERIFICATION TASKS

This appendix provides a description of the verification tasks mentioned in the body of this methodology. It also provides reasoning for choosing each verification option. Each verification task below has a number that begins with the prefix "VE." (Validation tasks that begin with the prefix "VA" are described in appendix C.) The verification tasks are organized by the question they intend to answer. The verification questions, which are included below, are numbered VE-1 through VE-8. Each task number begins with the number of the question it is intended to answer. For example, VE-1-1 is the number for the first task under question VE-1. A check mark indicates a task that should be done for every verification effort.

The resulting product from these tasks should be V&V reports documenting the results of the findings. See paragraph 3-5 and appendix C for additional information.

√ **VE-1: Is the intended use documented?** *Answer this question for every V&V effort.*

VE-1-1: Review requirements documentation for description of intended use. *This task involves reviewing the requirements documentation to ensure that it documents and supports the intended use of the M&S. The V&V team should report the results (see paragraph 3-5a(2) for more information).*

√ **VE-1-2: Document intended use.** *V&V team should document the intended uses of the M&S in the V&V Implementation Plan (appendix E, paragraph 4). The plan should define the problem that the M&S is intended to solve, including specific questions that the M&S will be expected to help answer.*

VE-2: Are the requirements complete, clear, testable, and consistent with each other? *The V&V team should answer this question when the M&S requirements are documented. (Note: Requirements in a requirements document are normally denoted by the sentences with the word "shall.") The V&V team should do tasks VE-2-1, VE-2-3, VE-2-4, and VE-2-5 for all M&S with documented requirements. If a requirements document does not exist for the M&S, the V&V team should recommend that a requirements document be written if at all possible. Task VE-2-2 is applicable when there is more than one level of requirements documentation. The V&V team should do task VE-2-6 when a requirements review is scheduled or needs to be scheduled.*

VE-2-1: Review requirements for clearness, testability, and consistency. *This task involves reviewing the requirements documentation to ensure that the documentation is clear and consistent. The V&V team should report the results. (See paragraph 3-5a(2) for additional information.) This includes:*

- *Structure: Verify that the requirements document is adequately organized. Some specific questions to answer are:*

- *Is the table of contents correct?*
- *Is there a bibliography of prerequisite publications?*
- *Are the references complete enough to locate the publication?*
- *Are the references available?*

- *Does the organization of the document contribute to the ease of finding information?*
- *Does the format comply with applicable standards?*

- *Readability: Verify that the document is readable. Salient contributors to readability include paper size, use of color, print font, print size, size of figures, etc.*

- *Consistency: Verify internal consistency within the document and between it and other M&S documents.*

- *Clearness: Verify that each requirement is unambiguous. An entirely clear requirement should be interpreted identically by all readers. For example, "The simulation shall seem real to the user" is an unclear requirement, because the phrase "seem real" can be interpreted differently by different people. Such a requirement should be rewritten to clarify what is wanted. An example of a requirement more clearly stated is, "The color scheme of all M1A1 tanks seen in the simulation shall be visually indistinguishable from that of an actual M1A1 tank painted in desert camouflage colors." Here, the requirement is stated in such a way that readers are likely to interpret it in the same way. Some specific questions to answer are:*

  - *Are examples clear?*
    - *Used where necessary?*
    - *Relevant where used?*
    - *Contribute to understanding?*

  - *Are diagrams, pictures, or the visual materials clear?*
    - *Used where necessary?*
    - *Relevant where used?*
    - *Contribute to understanding?*
    - *Clearly rendered?*
    - *Appropriate level of detail?*

  - *Is the terminology clear?*
    - *Consistent throughout the document?*
    - *Consistent with other system documents?*
    - *Conforms to applicable standards?*
    - *Is there a glossary, if appropriate?*
    - *Are the acronyms utilized correctly?*
    - *Are definitions clear and correct?*

- *Completeness and correctness: Verify that all user requirements have been included. Verify the requirements are complete. For example, "The input window shall be 4 inches high and 2.4 inches wide" is a complete requirement. However, "The input window shall be 4 inches high" is incomplete because one of the dimensions of the two-dimensional window has been left out. Some specific questions to answer are:*

  - *Are all essential topics complete?*
  - *Is there completeness in detail, assumptions, facts, unknowns?*
  - *Is there excessive dependence on external references?*
  - *Are there any errors of fact?*

- *Testability: Verify that the success of meeting a requirement can be determined with a finite and reasonable set of test cases. For example, "The system shall have a user-friendly interface" is entirely untestable (in addition to being ambiguous) because user-friendly is undefined. On the other hand, "The system shall allow the user to enter the functional parameters of the missile under test via a pop-up window" is entirely testable. All the tester has to do is determine if a reasonable means has been provided to produce a pop-up window for the required data entry.*

VE-2-2: Verify traceability of lower and higher-level requirements. *If the M&S contain higher and lower-level requirements, they should be traceable and consistent with each other. If the developer created a traceability matrix for the requirements, the V&V team should verify it is correct. If the developer has not developed a traceability matrix, the V&V team should create one. The V&V team should report the results of the traceability analysis as indicated in paragraph 4-5a(2). To create a traceability matrix, the V&V team should create a table or spreadsheet with the higher-level requirements across and the lower-level requirements down (or vice versa). Compare each higher-level requirement with each lower-level requirement. When a higher-level requirement in a particular column is met by a lower-level requirement in a particular row, enter an "M" in the corresponding cell in that row and column.. For each requirement only partially met, enter a "P" in that cell. Do the same thing for each lower-level requirement. After each requirement is compared, the V&V team determines if a requirement is completely traceable. Higher-level requirements that are not traceable to lower-level requirements indicate functionality that is being left out. Lower-level requirements that are not traceable to higher-level requirements indicate functionality not required and may mean additional cost down the road if not corrected.*

Note: Each level of system refinement may result in requirements not directly traceable to higher-level requirements. For example, a system architectural design that creates two subsystems may result in requirements about how the subsystems will interface, even though these interfaces are not covered in the system requirements. Such requirements may be traced to a general requirement such as "system implementation" or to the system design decisions that resulted in their generation.

Below is an example of a traceability matrix that compares system and CI requirements. In this case each system requirements should be traceable to the CI requirements and each CI requirement should be traceable back to a system level requirement.

	A	B	C	D	E	F
1	CI \ System Reqs \ Reqs	S-1	S-2	S-3	S-4	M, N, or P?
2	CI-1-1	M				M
3	CI-1-2		P	P		M
4	CI-2-1			P		P
5	CI-2-2		P			P
6	CI-2-3					N
7	M, N, or P?	M	P	M	N	P

Table B-1. Requirements Traceability

The matrix shows the following:

- *Requirement CI-1-1 is met by requirement S-1. This is indicated by the "M" in cell B2. Since both of these requirements are totally met, there is an "M" entered in cell F2 and B7.*

- *Requirement C1-1-2 is partially met by requirements S-2 and partially met S-3 – indicated by a "P" in cells C3 and D3. Since all of requirement*
  CI-1-2 is met by S-2 and S-3, there is an "M" in cell F3.

- *Requirement CI-2-1 is partially met by S3 – indicated by "P" in cell D4. Since this requirement is only partially met, there is a "P" in cell F4.*

- *Requirement CI-2-2 is partially met by requirement S-2 – indicated by the "P" in cell C5. Since this requirement is only partially met, there is a "P" in cell F5.*

- *Since requirement CI-2-3 is not met by any of the system requirements, there is a "N" in cell F6. This indicates that requirement CI-2-3 may not be needed.*

- *Requirement S-2 is partially met by requirements CI-1-2 and CI-2-2. Since these two requirements do not totally satisfy S-2 there is a "P" in cell C7.*

- *Requirement S-3 is totally met by CI-1-2 and CI-2-1 together – indicated by the "M" in cell D7.*

- *Requirement S-4 is not met by any of the CI requirements. This indicates missing functionality.*

VE-2-3: Verify adequacy of system engineering requirements. *Review requirements documentation for adequacy of system engineering requirements and report the results. (See paragraph 3-5a(2) for more information.) The system-level requirements describe the M&S as a whole and may be comprised of hardware and/or software. This task includes ensuring the following types of requirements are adequately included, as appropriate, in the requirements documentation: (These were adapted from the MIL-STD 498, System/Subsystem Specification Data Item Description.)*

- *Adaptation: Requirements concerning installation-dependent data that the M&S is required to provide and operational parameters that the M&S is required to use that may vary according to operational needs.*

- *Safety: Requirements concerned with preventing or minimizing unintended hazards to personnel, property, and the physical environment. This applies to both hardware and software systems.*

- *Security and Privacy: Requirements concerned with maintaining security and privacy. This should include, as applicable, the security/privacy environment in which the system must operate, the type and degree of security or privacy to be provided, the security/privacy risks the system must withstand, required safeguards to reduce those risks, the security/ privacy policy that must be met, the security/privacy accountability the*

system must provide, and the criteria that must be met for security/privacy accreditation.

- *Environmental: Requirements regarding the environment in which the system must operate. For software, this would include computer hardware and the operating system on which the software must run. For hardware, this would include environmental conditions the system must withstand during transportation, storage, and operation, such as conditions in the natural environment (e.g., wind, rain, temperature, geographic location) and the induced environment (e.g., motion, shock, noise, electromagnetic radiation).*

- *Computer Resources: Requirements regarding computer hardware that must be used by the software, or incorporated into the M&S hardware. This includes, as applicable, number of each type of equipment, type, size, capacity, and other required characteristics of processors, memory, input/output devices, auxiliary storage, communications/network equipment, and other required equipment.*

- *Design and Construction Constraints: Requirements that constrain the design and construction of the hardware and/or software. For hardware, this would include the physical requirements imposed on the system.*

- *Personnel/Human Factors: Requirements to accommodate the number, skill levels, duty cycles, training needs, or other information about the personnel who will use or support the system. Human factors engineering requirements should include, as appropriate, considerations for the capabilities and limitations of humans, foreseeable human errors under both normal and extreme conditions, and specific areas where the effects of human error would be particularly serious. Examples include requirements for adjustable-height workstations, color and duration of error messages, physical placement of critical indicators or buttons, and use of auditory signals.*

- *Logistics-Related: Requirements concerning logistics considerations, including system maintenance, software support, system transportation modes, supply-system requirements, impact on existing facilities, and impact on existing equipment.*

- *Packaging: Requirements for packaging, labeling, and handling the system and its components for delivery. Applicable military specifications and standards may be referenced if appropriate.*

VE-2-4: Verify adequacy of quality requirements. *Review requirements documentation for M&S quality assurance factors and report the results. (See paragraph 3-5a(2) for more information.) This includes ensuring that the following types of requirements are adequately included, as appropriate, in the requirements documentation:*

- *Functionality: the ability to perform all required functions.*
- *Reliability: the ability to perform with correct, consistent results.*
- *Maintainability: the ability to be easily serviced, repaired, or corrected.*
- *Availability: the ability to be accessed and operated when needed.*

- *Flexibility: the ability to be easily adapted to changing requirements.*
- *Portability: the ability to be easily modified for a new environment.*
- *Reusability: the ability to be used in multiple applications.*
- *Testability: the ability to be easily and thoroughly tested.*
- *Usability: the ability to be easily learned and used.*
- *Producibility: the ability to be easily produced.*

VE-2-5: Conduct interface analysis. *This technique is especially useful for V&V of interactive and distributed simulations (DOD 5000.59-P). Interface analysis consists of the following:*

- *Model Interface Analysis. A model interface analysis examines submodel-to-submodel interfaces within a model, hardware-software interfaces, or federate-to-federate interfaces within a federation, and determines if the interface structure and behavior are sufficiently accurate.*

- *User Interface Analysis. A user interface analysis examines the model's user-interface and determines if it is human engineered to prevent errors during the user's interactions with the model. It also assesses how accurately this interface is integrated into the overall M&S.*

VE-2-6: Participate in requirements reviews. *The V&V team should partici-pate in any planned requirements reviews. The V&V team should request requirements reviews when necessary to ascertain the adequacy of the require-ments and/or resolve open issues regarding the specified requirements. Some things that could be reviewed at a requirements review include: intended use of the model; clearness, completeness, and testability of the requirements, (see VE-2-1); traceability (see VE-2-2); system engineering factors (see VE-2-3); quality assurance factors (see VE-2-4); interfaces (see VE-2-5); cost effectiveness; risk analysis; test planning; configuration management plans; schedules; etc.*

VE-3: Is the design clear, correct, and consistent? *The V&V team should answer this question when the M&S design is documented. The V&V team should do task VE-3-1 for all M&S with a documented design, tasks VE-3-2 when both requirements and design documentation exist, and task VE-3-3 when a design review is scheduled. The V&V team should request walk-throughs/inspections (task VE-3-4) as time and resources permit.*

VE-3-1: Review design documentation. *This task involves reviewing design documentation to ensure the documentation is clear and consistent. The V&V team should report the results. (See paragraph 3-5a(2) for additional information.) This includes:*

- *Structure: Verify the design document is adequately organized. Some specific question to answer are:*

  - *Is the table of contents correct?*
  - *Is there a bibliography of prerequisite publications?*
  - *Are the references complete enough to locate the publication?*
  - *Are the references available?*
  - *Does the organization of the document contribute to the ease of finding information?*
  - *Does the format comply with applicable standards?*

- *Readability: Verify the document is readable. Salient contributors to readability include paper size, use of color, print font, print size, size of figures, etc.*

- *Consistency: Verify internal consistency within the document and between other M&S documents.*

- *Clearness: Verify the design is unambiguous. An entirely clear design should be interpreted identically by all readers. Some specific question to answer are:*

    - *Are examples clear?*
        - *Used where necessary?*
        - *Relevant where used?*
        - *Contribute to understanding?*

    - *Are diagrams, pictures, or the visual materials clear?*
        - *Used where necessary?*
        - *Relevant where used?*
        - *Contribute to understanding?*
        - *Clearly rendered?*
        - *Appropriate level of detail?*

    - *Is the terminology clear?*
        - *Consistent throughout the document?*
        - *Consistent with other system documents?*
        - *Conforms to applicable standards?*
        - *Is there a glossary, if appropriate?*
        - *Are the acronyms utilized correctly?*
        - *Are definitions clear and correct?*

- *Completeness and Correctness: Verify the design is complete and all applicable system engineering (see VE-2-3), quality assurance (see VE-2-4), and interface requirements (see VE-2-5) are adequately met. Some specific questions to answer are:*

    - *All essential topics complete?*
    - *Is there completeness in detail, assumptions, facts, unknowns?*
    - *Is there excessive dependence on external references?*
    - *Are there any errors of fact?*

As applicable, review the adequacy of the software design:

- *Unit Checks: Check equations to ensure that measurement units are consistent throughout the equations*

- *Algorithm Checks: Compare algorithms and equations to authoritative documentation to determine their fitness for use in the target application. Comparison to other acceptable methodologies is also applicable. This check attempts to determine whether acceptable, standard algorithms and equations have been used in M&S development.*

- *Subject Matter Expert (SME) Review: Independent, knowledgeable experts review algorithms and equations used in the M&S. Such reviews often*

highlight hidden assumptions, and their impacts on M&S results can result in more efficient design and implementation. Unfortunately, rigorous reviews by SMEs require considerable preparation time and resources.

- *Rule Verification: SMEs familiar with the intended use of the system should verify the rules. Verification of rule-based systems must address the completeness and correctness of the knowledge base. It is also important to detect rule redundancy since this affects run-time and may cause inconsistencies and other difficulties during the maintenance phase.*

As applicable, review the adequacy of the hardware design:

- *Review adequacy of drawings including schematic diagrams.*
- *Review adequacy of the design in the following areas, as appropriate:*
  - *Electrical design*
  - *Mechanical design*
  - *Power generation and grounding*
  - *Electrical and mechanical interface compatibility*
  - *Mass properties*
- *Review the adequacy of interface control drawings.*

VE-3-2: Verify traceability of design and requirements. *The V&V team should verify that the design is traceable to the requirements. Use the lowest level of requirements if there is more than one level of requirements (e.g., CI requirements).*
If the developer created a traceability matrix for tracing the requirements and design units, the V&V team should verify it is correct. If the developer has not developed a traceability matrix, the V&V team should create one. The V&V team should report the results of the traceability analysis as indicated in paragraph 3-5a(2). To create a traceability matrix, the V&V team should create a table or spreadsheet with the requirements across and the design units down (or vice versa). Compare each requirement with each design unit. When a requirement in a particular column is met by a design unit in a particular row, enter an "M" in the corresponding cell in that row and column. For each requirement only partially met, enter a "P" in that cell. Do the same thing for each design unit. After each requirement and design unit are compared, the V&V team determines if the design and the requirements are completely traceable. Requirements that are not traceable to the design requirements indicate functionality that is being left out. Design units that are not traceable to requirements indicate functionality not required and may mean additional cost down the road if not corrected. See VE-2-2 for an example of a traceability matrix.

VE-3-3: Participate in design reviews. *The V&V team should participate in any planned design reviews. The V&V team should request design reviews when necessary to resolve open issues regarding design decisions. Some things that could be reviewed at a design review include: clearness and completeness of the design (see VE-3-1); adequacy of software and/or hardware design (see VE-3-1); adequacy of meeting system engineering requirements (see VE-2-3); adequacy of meeting quality assurance requirements (see VE-2-4); adequacy of meeting interface requirements (see VE-2-5); traceability of design and requirements (see VE-3-2); cost effectiveness; risk analysis; test planning; configuration management; schedules; etc.*

VE-3-4: Participate in design walk-throughs/inspections. *Design walk-throughs and inspections involve a more detailed examination of the design than a design review. Design walk-throughs and inspections involve an intricate line-by-line examination of the design. The main thrust of a walk-through or inspection is to detect and document faults. To be successful, it must not to be used as a performance appraisal of the developmental team. A walk-through is less formal, has fewer steps, and does not use a checklist to guide or a written report to document the team's work. By comparison, an inspection takes much longer than a walk-through; however, the extra time can be justified because an inspection is a powerful and cost-effective way of detecting faults early in the M&S develop-mental cycle. (Reference DOD VV&A Recommended Practices Guide for more information.)*

VE-4: Does the simulation conform to the documented design?

VE-4-1: Verify traceability of design to test cases. *The V&V team should verify the test cases are traceable to the design. If the developer created a traceability matrix for tracing the test cases and design units, the V&V team should verify it is correct. If the developer has not developed a traceability matrix, the V&V team should create one. The V&V team should report the results of the traceability analysis as indicated in paragraph 4-5a(2). To create a traceability matrix, the V&V team should create a table or spread-sheet with the design units across and the test cases down (or vice versa). Compare each design unit with each test case. When a design unit in a particular column is met by a test case in a particular row, enter an "M" in the corresponding cell in that row and column. For each design unit only partially met, enter a "P" in that cell. Do the same thing for each test case. After each design unit and test case are compared, the V&V team determines if the test cases and the design are completely traceable. Design units that are not traceable to test cases indicate functionality that not being tested. Test cases that are not traceable to design units indicate the test cases that are unneeded. See VE-2-2 for an example of a traceability matrix.*

VE-4-2: Witness tests to ensure design functions are tested. *The V&V team should first verify that the test cases test every design function (task VE-4-1) and then verify that the test plan is followed. See paragraph 3-5d for more information.*

VE-4-3: Test design conformance. *Test the model to determine if all design function were implemented. See paragraph 3-5d for more information.*

VE-4-4: Participate in code walk-throughs/inspections. *Code walk-throughs and inspections involve an intricate line-by-line examination of the code. This task should be done only for specific high-risk areas of the code. The main thrust of a walk-through or inspection is to detect and document faults. It is not to be used as a performance appraisal of the developmental team. See VE-3-4 for more information about walk-throughs and inspections.*

√ **VE-5: Does the simulation conform to the documented requirements?**

VE-5-1: Verify traceability of requirements to test cases. *The V&V team should verify that the test cases are traceable to the requirements. If the developer created a traceability matrix for tracing the test cases requirements, the V&V team should verify that it is correct. If the developer has not developed a traceability matrix, the V&V team should create one. The V&V team should report the results of the traceability analysis as*

indicated in paragraph 3-5a(2). To create a traceability matrix, the V&V team should create a table or spread-sheet with the requirements across and the test cases down (or vice versa). Compare each requirement with each test case. When a requirement in a particular column is met by a test case in a particular row, enter an "M" in the corresponding cell in that row and column. For each requirement only partially met, enter a "P" in that cell. Do the same thing for each test case. After each requirement and test case are compared, the V&V team determines if the test cases and the requirements are completely traceable. Requirements that are not traceable to test cases indicate functionality that not being tested. Test cases that are not traceable to requirements indicate the test cases are unnecessary. See VE-2-2 for an example of a traceability matrix.

VE-5-2: Conduct/witness acceptance test. *Operational test the model with the actual hardware and data to determine whether all requirements are satisfied. The V&V team should first verify that the test cases test every functionality (task VE-5-1). Acceptance testing is usually conducted by either the V&VA agent and the M&S application sponsor or the developer's quality control group in the presence of the sponsor's representatives (reference DOD VV&A Recommended Practices Guide).*

VE-5-3: Prepare breadth of testing metric report (% requirements tested and % requirements passed). *This metric addresses the degree to which required functionality has been successfully demonstrated as well as the amount of testing that has been performed. This metric is commonly applied to large software developmental efforts. See DA Pamphlet 73-7 for detailed information about how to use this metric.*

VE-6: Is the simulation being properly developed?

VE-6-1: Conduct compliance testing. *Compliance testing compares the simulation to required security and performance standards. These techniques are particularly useful for testing federations of distributed and interactive M&S. Compliance testing methods for HLA compliance have been developed and are available from DMSO (reference DOD VV&V Recommended Practices Guide). Compliance testing techniques include:*

- *Authorization testing: test how accurately different levels of security access authorization are implemented in the simulation and how properly they comply with established rules and regulations. The test can be conducted by attempting to execute a classified model within a federation or by using classified input data to run a simulation without proper authorization.*

- *Performance testing: test whether all performance characteristics are measured and evaluated with sufficient accuracy and if all established performance requirements are satisfied.*

- *Security testing: test whether all security procedures are implemented correctly and properly. For example, penetrating the simulation while it is running and breaking into classified components such as secure databases can be attempted. Security testing evaluates the adequacy of protective procedures and countermeasures.*

- *Standards testing: substantiates that the M&S application is developed with respect to the required standards, procedures, and guidelines.*

VE-6-2: Review Configuration Management Procedures. *Configuration Management (CM) is an integral part of the systems engineering management process for system definition and control. CM normally employs three types of configuration baselines – functional (e.g., system requirements documentation), allocated (e.g., CI requirements documentation), and product (e.g., design documentation, source/executable code, engineering drawings). Once a baseline has been established, the developer must control and maintain the originals of the currently approved configuration documentation. The V&V team should verify that the developer/maintainer is doing the following throughout the M&S life cycle:*

- *Prepare/update a CM Plan for the M&S.*
- *Use the CM Plan as the basis for performing CM activities.*
- *Internal Control: Control changes to baselines according to a documented procedure. Figure 2-4 of this methodology shows how these baselines fit into the developmental process. Internal control includes:*
    - *Establishing a documentation library and implementing procedures for controlling the documents residing within the documentation library.*
    - *Establishing a drawing library and implementing procedures for controlling the drawings, computer aided design (CAD), and computer aided manufacturing (CAM) instructions residing within the drawing library.*
    - *Creating software products from the software baseline library and establishing the library as a repository for software baselines. Users and developers should not be able to change baseline versions of the source and executable code.*
    - *Recording the status of CIs/units according to a documented procedure.*
    - *Providing a means which M&S users and application sponsors can input to the M&S enhancement process.*
    - *Initiating, recording, reviewing, approving, tracking change reports and problem reports for all CIs/units according to a documented procedure. This includes documenting the following:*
        - *The reason for the change.*
        - *Description of the change.*
        - *Impact on users.*
        - *Expected impact on M&S results.*
    - *Developing standard reports documenting CM activities and the contents of baselines. Making reports available to affected groups and individuals.*
- *External Control: Control the release of these products according to a documented procedure (DA Pamphlet 5-11). This includes:*

- *Documenting all M&S release requests, and if approved, an archived copy of the released code.*

- *Establishing and administering user group activities in paragraph 7-4 of AR 5-1.*

- *Establishing and administering procedures through which users may receive quick response help and debugging assistance.*

- *Establishing procedures that allow users to report code and documentation errors. This includes correlating fixes applied to reported difficulties.*

- *Archiving of M&S Uses: Archiving is the management of a historical record of the M&S and its applications (DA Pamphlet 5-11). This function should be performed by M&S users, but archived data should be available to the proponent and other users of the M&S. Items normally archived include:*

  - *Source and executable code*
  - *Input data*
  - *Output data*
  - *Documentation of the use of M&S results*

- *Storage: Storage of the information which results from each major use of the M&S will ensure a proper audit trail and library of data for use in the future VV&A procedures. The application of a particular M&S constitutes an accreditation of the M&S for that specific use. Documentation and archival of this use will assist in future accreditation procedures.*

- *Configuration Audits. Configuration audits include the Functional Configuration Audit (FCA) and the Physical Configuration Audit (PCA). The FCA is a formal examination of the functional characteristics of a CI, prior to acceptance, to verify that the item has achieved the requirements specified in its functional and allocated configuration documentation. The PCA is a formal examination of the "as-built" configuration of a CI against its technical documentation to verify the CI's product baseline. (See MIL-STD 973 for additional information.)*

VE-6-3: Conduct/Witness Configuration Audits. *Configuration audits include the Functional Configuration Audit (FCA) and the Physical Configuration Audit (PCA). The FCA is a formal examination of the functional characteristics of a CI, prior to acceptance, to verify that the item has achieved the requirements specified in its functional and allocated configuration documentation. The PCA is a formal examination of the "as-built" configuration of a CI against its technical documentation to verify the CI's product baseline. See MIL-STD 973 and VE-6-2 for additional information.*

VE-6-4: Complexity metric report. *The metric is commonly applied to large software developmental efforts. Source code or program design language (PDL) is the material examined for determining complexity. Automated tools should be used to compute the measures accurately and consistently. The complexity metric provides a means to measure and evaluate the structure of software units. Software that is more complex is harder to understand, test adequately, and maintain.*

Additionally, a highly complex unit is more likely to contain embedded errors than a unit of lower complexity. The Army complexity metric allows selection from five different measures: (See DA Pamphlet 73-7 for additional information about this metric.)

- *McCabe's cyclomatic complexity: Relative degree of effort to test or maintain a software unit (based on the number of ways control could flow through the unit).*
- *Halstead's length, vocabulary and volume: Relative degree of effort to test or maintain a software unit (based on the amount of data and number of operations performed on them).*
- *Control flow: "Unstructured" changes in control flow though unit.*
- *Source lines of code: Size.*
- *Percent comment lines: Understandability and maintainability.*

VE-7: How much has the simulation been tested and how free of problems is it?

VE-7-1: Prepare depth of testing metric report (% tested and passed testing). *This metric is commonly applied to large software developmental efforts. Automated tools may be used to compute this measure. The depth of testing metric measures the amount of testing achieved on the software architecture, that is, the extent and success of testing the possible control and data paths and conditions within the software. This is often described as "white box" testing since there is visibility into how the software is constructed. The four depth attributes and criteria for success are:*

- *Path: Path is successfully executed at least once.*
- *Statement: Statement is successfully executed at least once.*
- *Input: Input is successfully tested with at least one legal entry and one illegal entry.*
- *Decision point: Decision point is successfully exercised with all classes of legal conditions as well as one illegal condition.*

The test coverage measure equals the number of attribute occurrences tested divided by the number of occurrences of the attribute. Overall success equals the number of attribute occurrences passed divided by the number of occurrences of the attribute. (See DA Pamphlet 73-7 for more information.)

VE-7-2: Prepare fault profiles report (open versus closed anomalies). *This metric is commonly used in software developmental efforts. The fault profiles metric is a summary of problem/change report data collected by the corrective action system. This metric provides insight into the number and type of deficiencies in the current baseline, as well as the developer's ability to fix known faults. A common display is*

the cumulative numbers of faults detected (problem reports opened) and closed, over time. (See DA Pamphlet 73-7 for more information.)

VE-7-3: Prepare reliability metric report (Mean time between failures). *The reliability metric expresses the contribution to reliability. Number of system failures and the time it takes to restore the system to its previous operational condition are tracked. (See DA Pamphlet 73-7 for more information.)*

VE-8: Is the simulation on schedule and cost as planned?

VE-8-1: Prepare cost metric report. *The cost metric provides insight into the actual cost expenditures for developmental tasks, compared to the initial cost estimates. The cost/schedule control systems criteria, described in DODI 7000.2, is used to track cost, schedule, and technical performance. The first step in applying the cost metric is to identify the appropriate work tasks, or activities, as cost elements in a program. Cost accounting elements are identified through the use of a Work Breakdown Structure (WBS). Procedures for developing a WBS and its hierarchy of levels are defined in MIL-HDBK-881. The following data items are collected for each reported WBS activity (see DA Pamphlet 73-7 for more information):*

- *Budgeted Cost of Work Scheduled*
- *Budgeted Cost of Work Performed*
- *Actual Cost of Work Performed*

VE-8-2: Prepare schedule metric report. *The schedule metric indicates the degree to which program events adhere to a work schedule plan and complement the schedules typically used on programs. The changes to the schedule will indicate the level of risk associated with achieving future program milestones and providing key deliverables on time. For each item selected for schedule metric monitoring, collect:*

- *Planned start date*
- *Planned end date*
- *Actual start date*
- *Actual end date*

VE-8-3: Prepare computer resource utilization metric report. *This metric shows the degree to which estimates and measurements of computer resources are changing or approaching the limits of resource availability. Constraints in computer resource utilization can lead to poor performance in the operational environment. The primary objective is to determine whether computer resources are adequate to handle the most demanding of the anticipated operational workloads. A second objective is assurance that reserve capacity for future maintenance and enhancement exists prior to initial fielding. The minimum sets of resources to monitor are central processing units (CPUs), input/output channels, storage devices, and memory. (See DA Pamphlet 73-7 for more information.)*

VE-8-4: Prepare manpower metric report. *Track planned and actual effort and staffing. (See DA Pamphlet 73-7 for more information.)*

VE-8-5: Prepare developmental progress metric report. *Track planned and actual work unit completed. (See DA Pamphlet 73-7 for more information.)*

VE-8-6: Prepare requirements stability metric report. *The requirements stability metric indicates the degree to which changes in the software requirements or changes in the developer's understanding of the requirements are affecting the developmental effort. For each software CI, collect: (See DA Pamphlet 73-7 for more information.)*

- *Software requirements discrepancy status (cumulative total detected and cumulative total resolved).*
- *Total number of source lines of code (SLOC).*
- *Total number of requirements.*
- *Number requirements added due to approved engineering change proposals (ECPs).*
- *Number of requirements modified due to approved ECPs.*
- *Number of requirements deleted due to approved ECPs.*
- *Number of SLOC affected by approved ECPs.*
- *Number of software units affected by approved ECPs.*
- *Number of ECPs generated from requirements changes.*

VE-8-7: Prepare design stability metric report. *This metric is composed of two measures. The design stability measure tracks changes made to the design of software. The design progress measure shows how the completeness of the design is advancing over time and provides a context for viewing the design stability measure in relation to the total projected design. (See DA Pamphlet 73-7 for more information.)*

VE-8-8: Participate in test readiness review. *The V&V team should participate in planned test readiness reviews. When necessary, the V&V team should request a test readiness review to resolve open issues regarding one or more of the following: status of the test environment, test cases and procedures for qualification testing, and status of M&S to be tested. Some specific things that could be reviewed include: requirements changes, design changes, test plans and descriptions, test procedures, test cases, results of previous tests, test resources, test limitations, implementation problems, schedules, and documentation updates.*

APPENDIX C

DESCRIPTION OF VALIDATION TASKS

This appendix provides a description of the validation tasks mentioned in the body of this methodology. It also provides reasoning for choosing each validation option. Each validation task below has a number that begins with the prefix "VA". (Verification tasks that begin with the prefix "VE" are described in appendix B.) The validation tasks are organized by the question they are intended to answer. The validation questions, which are included below, are numbered VA-1 and VA-2. Each task number begins with the number of the question it is intended to answer. For example, VA-1-1 is the number for the first task under question VA-1. A check mark indicates the task should be done for every validation effort.

The resulting product from these tasks should be V&V reports documenting the results of the findings. See paragraph 3-5 and appendix F for additional information.

√ **VA-1: Does the simulation requirements documentation require that the simulation represent the real world to an adequate degree of fidelity for the intended use?** *This question should be answered for every V&V effort.*

VA-1-1: Review requirements documentation for adequate model fidelity requirements. *The V&V team should review the requirements documentation to ensure that it contains fidelity requirements that describe how well the model must replicate the real world to meet the model's intended use.*

√ **VA-1-2: Document evaluation criteria for model fidelity.** *V&V team should document the requirements for model fidelity in the V&V Implementation Plan (see appendix E, paragraph 7b). The V&V Implementation Plan should describe how the model results and real world data will be compared and how well the model must replicate the real world to meet the model's intended use.*

√ **VA-2: Simulation adequately tested for fidelity in representing the real world?** *This question should be answered for every V&V effort. The question can be answered by a combination of developer tests (VA-2-1 and VA-2-2), output validation methods that require real world data (VA-2-3 through VA-2-6), and/or other validation methods that don't require real world data (VA-2-7 through VA-2-10). Validation methods that utilize real world data provide the most credibility.*

In some cases, the V&V team may chose to witness the developer's tests. In this case, the V&V team should do the following two tasks:

VA-2-1: Review developer's test plan to ensure it contains adequate tests for model fidelity. *The V&V team should determine which evaluation criteria (see task VA-1-2) are covered in the test plan. If all of the criteria are not met, the V&V team should recommend changes to the test plan and/or do their own testing to evaluate the missing criteria.*

VA-2-2: Witness developer's test(s) to ensure it is adequate for model fidelity. *The V&V team should ensure that the developer follows the test plan the V&V team reviewed in task VA-2-1. If the developer did not provide a test plan, the V&V team should witness the test and note which evaluation criteria were met (see task VA-1-2). If there were any criteria not fully met, the V&V team should either recommend*

that the developer do additional tests or the V&V team should conduct the additional tests that are needed.

Tasks VA-2-3 through VA-2-6 *are examples of output validation (or operational validation). Output validation provides more credibility than other validation methods because it involves the direct comparison of model results to real world data where the data will specifically validate the model. The following outline contains the steps necessary to validate an M&S using output validation methods. Note this validation process takes place near the end of the model developmental process. Based on the results of the validation process, it may be necessary to modify one or more parts of the M&S. If this becomes necessary, the model description may need to be modified, and the module and system tests will need to be redone. The steps in the output validation process are:*

(1) Identify and/or define the intended use of the model (see verification tasks VE-1-1 & VE-1-1-2). The V&V team should include a description of the intended use in the V&V Implementation Plan.

(2) Identify those elements of the model where accurate representations of reality are critical to support this intended use.

(3) Prioritize these elements.

(4) Identify sources of real world data that can be used to provide comparisons to the model characteristics or responses identified in step 2.

(5) Outline the evaluation criteria in the V&V Implementation Plan. Describe how the model results and the real world data will be compared (VA-1-2).

(6) Run the simulation and compare the results from the model to the real world data. Standard statistical tests can sometimes be used to determine whether the differences in the means, variances, and probable distributions generating the two sets of data are significantly different. Time-dependent behavior of the data may also be statistically compared. If the data cannot be statistically analyzed, the V&V team should ask personnel familiar with the behavior of the real system if they can differentiate between the two data sets (VA-2-3).

(7) Document both the tests and all of the results. Consider using graphical representations of the results versus providing only the raw data. Include a discussion of both the strengths and weakness of the model to support the intended application(s). Note: Perfect validation is not possible. The intent is to demonstrate how well or how poorly the model and the real world match. The accreditation process will determine if the match is good enough for the accreditation agent's intended purpose.

Some variations of output validation are given in tasks VA-2-3 through VA-2-6 which are described below. The V&V team may use other variations of the output validation method.

VA-2-3: Ask experts to differentiate between model and real world data flow, controls, and outputs (i.e., Turing test). *A Turing test is based upon the expertise of people knowledgeable about the real world system. The experts compare two sets of results, one from the model and one from the real world system, under the same input conditions. Without knowing which data set is which, the experts try to differentiate between the two. If they are successful, the experts describe how they*

are different. This provides valuable feedback for correcting the model. If the experts cannot differentiate between the two, confidence in the model's validity is increased (DA VV&A Recommended Practices Guide).

VA-2-4: Model-Test-Model - Use T&E results in an iterative method of successive model improvements until validated to the desired degree. *The Model-Test-Model approach is part of the STEP process, where test data are collected to make the model more accurately represent the actual system and operating environment as time progresses (Draft STEP Guidelines). The Model-Test-Model process is accomplished with the following steps: model the scenario; observe test play; constrain the M&S to test conditions; compare M&S measures to observations; adjust the M&S; rerun the M&S and repeat the cycle as necessary. The basic phases of Model-Test-Model are:*

- *Pretest Modeling Phase. Estimate a range of test results prior to the conduct of record trials/events. Pretest modeling focuses on test design issues such as tactical soundness, adequacy of scenarios to address all critical issues and test objectives, and the identification of appropriate data to be collected during the test. M&S support personnel must be thoroughly familiar with the Test and Evaluation Master Plan, the Operational Requirements Document for the system, the design parameters of the test phase, and test site information relating to data collection and timing. This ensures the full spectrum of M&S capabilities needed to approximate the environment, the systems, and the scenario is available. During this phase, functional validation is a useful technique to ensure that selected portions of the M&S can represent specific test objectives. M&S support personnel and test support personnel, as part of an overall test team, should work together well in advance of the actual field testing, to ensure that test data are collected in a form usable by the models and simulations, that all required data are collected (for example, data describing engagement procedures, environment conditions, system performance, and so forth). Results from pretest modeling phase can be used to assist in planning the field test and in planing details of the data collection and analysis effort (DA Pamphlet 5-11).*

- *M&S Measures and Test Observation Comparison Phase. This phase begins with conducting the test. The actual field test results are then compared to the pretest modeling results as part of the M&S validation process, and to fine tune the M&S (if needed) for further iterations of the Model-Test-Model.*

- *Post-Test Modeling Phase. M&S personnel must integrate the test data to demonstrate that the M&S can replicate the observed test results within reasonable tolerances. The M&S algorithms or accompanying databases may require modification so that the model yields results that correlate with observed test results. The successful completion of this phase provides the capability to extend the scope of the test to address issues (environment, threat, terrain, weather, and so forth) that may not have been addressed within the constraints of the test itself (DA Pamphlet 5-11).*

VA-2-5: Graphically compare model variables with real world variables. *Graphical comparison is a subjective, inelegant, and heuristic, yet practical approach, especially as a preliminary validation step. The V&V team graphs model and real world variables over time to investigate characteristics such as similarities*

in periodicity, skew, number, and location of inflection points; logarithmic rise and linearity; phase shift; trend lines; and exponential growth constants (DA VV&A Recommended Practices Guide).

VA-2-6: Compare animation/graphics playback of simulation with real world. *Visualization and animation greatly assist in model V&V. This method is particularly useful for validating representations of vehicle/unit movement and weapon firings (DA Pamphlet 5-11). Displaying graphical images of internal and external dynamic behavior of a model is very useful in uncovering errors. Visualizing the model as it executes and comparing it with real world can help identify discrepancies. It does not, however, guarantee model correctness and should be used with caution (DA VV&A Recommended Practices Guide).*

Tasks VA-2-7 through VA-2-10 *are examples of validation methods that don't require real world data. The V&V team can use these methods when real world data is not available and/or to validate models earlier in the developmental cycle. When examining the different types of M&S in use in the Army, it becomes apparent that not all models can be validated using real world data. That is, there are models in use where real world data are not available. Examples include combat M&S of distributed communications networks operating in a hostile electronic warfare environment. In order to validate these types of models several different methods have been developed. Some examples include: comparison to other models (VA-2-7); face validation/expert opinion (VA-2-8) ; functional decomposition (VA-2-9); and predictive validation (VA-2-10); . Models that can be validated using output validation (Tasks VA-2-3 through VA-2-6) can be also be validated using these other methods. It should be noted that some of these techniques can be used during the developmental process, thus helping the model developer identify problems earlier, while others can not be exercised until after the model has been developed.*

VA-2-7: Compare model with another M&S that has already been accredited. *This compares code/units, documentation, input data, and test results with the test results of a model that has already been accredited for a similar use. For example, graphical displays of missile fly-outs, the battlefield, and output results may be compared among several M&S. This comparison has the limitation that the resulting degree of real world fidelity is only as good as that of the M&S with which it is being compared. Although not the real world, it may be the best that is reasonably available for comparison (DA Pamphlet 5-11).*

VA-2-8: Conduct Face Validation - *Use estimates and intuition of subject matter experts to compare model and real world behaviors subjectively. Face validation is where potential users and people knowledgeable about the real world system use their estimates and intuition to compare the model with real world behaviors. This is accomplished subjectively under identical input conditions, and judgement is made as to whether the model and its results are reasonable. Face validation is useful mostly as a preliminary approach to validation in the early stages of development. Except for a mature model with an extensive, well-documented VV&A history, viable validation efforts must generally use additional validation techniques (DOD 5000.59-P).*

VA-2-9: Validate simulation using functional decomposition - Validate the simulation's functional components and then validate how well the components fit together. *Decomposing the M&S into functional components is often a great aid in validating a model, especially large complex M&S. Functional area SMEs examine in detail the documentation, code, and output to determine the validity of*

each segment of the decomposed M&S. Then an analysis is accomplished of how well the pieces fit together, with the result being an overall validation of the M&S. Decomposition of the M&S should be sensitive to the intended uses of the M&S since this may drive the functional split and the level of decomposition. When used in conjunction with face validation of the overall M&S results, functional decomposition is extremely useful in reconfirming previous validation of a recently modified portion of the M&S (DA Pamphlet 5-11).

VA-2-10: Predictive validation. *Predictive validation requires past input and output from the system being modeled. The model, driven by the past input data, produces output that is compared with the corresponding past output data. The results validate the predictive ability of the model (DOD 5000.59-P).*

APPENDIX D

DESCRIPTION OF DATA V&V TASKS

The following tasks apply to data that are either a direct input by the user, or they are embedded constants that drive simulation characteristics. An M&S will probably fail output validation if the data that drive the simulation are inaccurate or inappropriate for the intended use. Data credibility is a major driver in M&S credibility.

√ **D-1-1: Verify Data - Review data used in the simulation to ensure it has been formatted correctly, units of measure have values within the allowable range.**
Data verification, according to DA Pamphlet 5-11, is the process of ensuring that the primary source data to be used in the M&S are converted to the correct input formats and units of measure and have values within the allowable range as specified in the design of the M&S. For hardware M&S, this could include some of the following: checking the calibration of the instrumentation or sensors used in a test, verifying the processed data have been converted properly from the raw data, checking for clipped data, checking that meters and recorders are zeroed or nulled, and checking the functioning of data recorder trigger thresholds.

√ **D-1-2: Validate data - Compare data with corresponding known real world or best-estimate values to ensure data are appropriate and reasonable for use.**
Data validation is the review of the data to compare them to corresponding known real world or best-estimate values. Data validation is typically performed by the M&S user to ensure that the data utilized in the M&S are appropriate and reasonable for its usage.

D-1-3: Conduct sensitivity analysis and/or stress tests. *Sensitivity analysis is performed by systematically changing the values of model input variables and parameters over some range of interest and observing the effect upon model behavior. Stress testing strains the M&S to determine where and when it will break under extreme workload conditions. Sensitivity analysis and stress testing can be applied to both verification and validation. Some special input tests that the V&V team perform are (DOD VV&A Recommended Practices Guide):*

- *Boundary Value Testing. Examine model accuracy by testing boundaries of input data. The underlying rationale is that most error-prone test cases lie along the boundaries.*

- *Equivalence Partitioning Testing. Partition the model input domain into equivalence classes in a way that a test of a representative value from a class is assumed to be a test of all values in that class.*

- *Extreme Input Testing. Run the M&S with only minimum values, maximum values, or an arbitrary mixture of minimum and maximum values for the model input variables. For example, this technique allows the model user to test a proposed weapon system against extreme conditions that may not be obtainable in actual system testing.*

- *Invalid Input Testing. Run the M&S under incorrect input data to determine whether the model behaves as expected. Unexplained behavior may reveal errors.*

- *Real-Time Input Testing. Use real-time input data collected from a real system to capture the timing relationships and correlation between data points.*

- *Self-Driven Input Testing. Run the M&S under input data randomly sampled from probabilistic models representing random phenomena in a real or future system.*

- *Stress Testing. Test the model under extreme workload conditions.*

- *Trace-Driven Input Testing. Run the M&S under input trace data collected from a real system. For example, a system can be instrumented with monitors that collect data by tracing all system events. The raw trace data are then refined to produce the real input data for testing the M&S.*

- *Statistical testing for repeatable stochastic M&S. Sensitivity analysis for repeat-able stochastic M&S can be performed with assurance that the resulting change in output is a result of the corresponding change in input. However, each use of the random number generator must be tested to ensure that the intended distributions result. Algorithms that contain random numbers must be tested with appropriate statistical tests to ensure that the outputs fit the postulated distributions. The number of replications that are required to produce stable output is one item unique to testing stochastic M&S that should be verified and documented (DA Pamphlet 5-11).*

- *Statistical testing for non-repeatable stochastic M&S. Sensitivity analysis is most difficult in M&S that incorporates direct human input since it introduces non-repeatable stochastic behavior. M&S with human decision-makers in the loop require analysis to determine if the decisions of the humans were within the realm of possibilities and that the resulting outcomes are reasonable (DA Pamphlet 5-11).*

APPENDIX E

V&V IMPLEMENTATION PLAN CONTENTS

The format of the V&V Implementation Plan and a detailed description of the contents of each paragraph follow:

1. Purpose. *Include a general statement that describes the purpose of this document.*

2. Background.

a. General M&S Description. *Include several paragraphs that describe the characteristics and features of the M&S. Include sufficient detail to allow for the understanding of the nature of the simulation, giving an idea of the magnitude and application of the simulation. Include a diagram of the M&S architecture. Identify original developer and current developmental activities.*

b. Configuration Management Procedures. *Include identification of the version of the M&S that is to undergo the V&V process, including the version numbers, and the location of the hardware, software, and data structures to be used in the V&V process. Identify the configuration manager and procedures as they pertain to the V&V process.*

c. Identification of Agencies. *Identify M&S developers, proponents, intended M&S users and application sponsors, and other contributors that assist in the M&S development or maturation. Include any data sources and data certifiers.*

3. V&V Responsibilities. *List agencies that have an active part in the V&V process along with their roles and responsibilities.*

4. Intended Uses of the M&S. *State the purposes for which the M&S is intended to be used. Identify the M&S category and, if applicable, the subcategory. Define the problem which the M&S is intended to solve, including specific questions that the M&S will be expected to help answer.*

5. Information Sources.

a. M&S Documentation. *Identify all M&S documentation.*

b. M&S Developers. *Identify personnel who played a part in the M&S development.*

c. SMEs. *Identify SMEs or other personnel who will define the real world as it pertains to the M&S application.*

d. Validation Data. *Identify real world data points for use as comparative data.*

e. Previous V&V. *Identify any previous V&V efforts.*

6. Verification Plan. *Describe overall verification effort and identify components to be evaluated.*

a. Methodology. *Describe the planned verification methods and why they were chosen. Define the scope of the effort and any limitations that may hinder the analysis. Include the depth of the planned tests, any decomposition strategy, and the intended depth of the investigation effort.*

b. Tasks and Milestones. *Include any specific agency tasking and responsibilities, resource requirements, verification organization and personnel assignments, and schedule for completion of each task. Describe any interdependencies among tasks. Include, as appropriate:*

(1) Requirements Verification (VE-1 and VE-2 tasks).

(2) Design Verification (VE-3 tasks).

(3) Implementation Verification (VE-4 and VE-5 tasks).

(4) Developmental Process Review (VE-6, VE-7, and VE-8 tasks).

7. Validation Plan. *Describe the overall validation effort and identify the components to be evaluated.*

a. Methodology. *Describe planned validation methods and why they were chosen. Define the scope of the problem and any limitations that may hinder the analysis. Include the depth of the planned tests, any decomposition strategy, and the intended depth of the investigation effort.*

b. Evaluation Criteria. *Describe sources of real world comparison data sets and how the model results and the real world data will be compared.*

c. Tasks and Milestones. *Include any specific agency tasking and responsibilities, resource requirements, validation organization and personnel assignments, and schedule for completion of each task. Also describe any interdependencies among tasks.*

d. Report Procedures and Deliverables. *Describe reporting procedures and deliverables.*

APPENDICES. *Add an appendix for each enhancement or modification that must undergo verification and/or validation. Include:*

(1) Description of the enhancement or fix and why the V&V team needs to perform additional V&V.

(2) Description of the V&V activities the V&V team plan to perform.

APPENDIX F

V&V REPORT CONTENTS

The format and a detailed description of the contents of each paragraph of the V&V Report follow:

1. Executive Summary of V&V Results. *Identify critical issues, trends, and/or sensitivities of the M&S. Also present the results of a reasonable, systematic examination of the V&V process of the M&S. This section should give an objective picture of the strengths and weaknesses in terms of the intended use. A specific statement regarding the confidence and credibility associated with the M&S in the context of its intended application is made in this section.*

2. Overview of V&V Plan. *Identify the V&V implementation document. Include a description of where and/or how the actual V&V effort differed from the original plan. Identify the agencies/personnel that performed the V&V.*

3. Description of Verification Process and/or Tests. *Include the descriptions of the decomposition and the level of depth achieved.*

   a. Requirements Verification. *Describe VE-1 and VE-2 tasks performed.*

   b. Design Verification. *Describe VE-3 tasks performed.*

   c. Implementation Verification. *Describe VE-4 and VE-5 tasks performed.*

   d. Developmental Process Review. *Describe VE-6, VE-7, and VE-8 tasks performed.*

   e. Unresolved Issues. *Provide a description of any verification problems and/or anomalies.*

4. Description of Validation Process and/or Tests. *Include the description of the decomposition and level of depth achieved if different from the verification description.*

   a. Evaluation Criteria. *Describe the real world data that were chosen for comparison and/or a brief background of any SMEs.*

   b. Validation Tasks. *Describe the validation tasks performed. Note any differences compared to original plan.*

   c. Unresolved Issues. *Provide a description of any validation problems and/or anomalies.*

5. Planned V&V Activities. *Describe any ongoing or currently planned V&V activities or additional V&V requirements resulting from this V&V effort.*

REFERENCES/ATTACHMENTS. *Attach V&V Plan and any other M&S related documents needed to describe the V&V effort.*

APPENDICES. *Add an appendix for each enhancement or modification that must undergo verification and/or validation. Include:*

a. Description of the enhancement or fix and why the V&V team performed new V&V.

b. Summarization of the findings of the new V&V activities.

c. Description of the tasks that were performed and level of detail.

APPENDIX G

ACCREDITATION PLAN CONTENTS

The format and a detailed description of the contents of each paragraph of the Accreditation Plan follow:

1. Background. *State why this M&S was chosen and to what problem it will be applied. This paragraph may duplicate the background paragraph in the V&V Implementation Plan. It should include a general description of the M&S, a list of all of the M&S developers and proponents, and a statement on which version of the M&S is targeted for accreditation.*

2. Accreditation Responsibilities. *Give a brief synopsis of the personnel and agencies involved in the accreditation process and why they were chosen. The accreditation proponent should be identified.*

3. Schedules, Milestones, and Resources. *Itemize the resources required for accomplishing accreditation. Include a schedule, with appropriate milestones, and briefly describe the event(s) that constitute each milestone.*

4. Intended Uses of the M&S. *Describe the roles for which the M&S is intended to be used and the specific use or class of application that this accreditation is addressing. Before any decisions are made about applying M&S to a given problem, the problem itself must be defined and articulated clearly enough to permit a precise specification of where M&S will play a role in the solution of the problem and how it will contribute to the solution of the problem.*

5. Information Sources. *Give a short summary of the sources being used to form the basis of the accreditation decision.*

   a. M&S Documentation.

   b. M&S Developers.

   c. V&V Personnel/Agencies.

   d. Identify V&V Plan, Report, and Findings.

6. Acceptability Criteria. *Acceptability criteria compose the most important content of the accreditation plan and should be developed as minimum criteria for accreditation. This paragraph should describe these criteria, how and why they were established, and how the degree of satisfaction of these criteria will be assessed. The acceptability criteria determine how well the M&S must do what it is required to do. The acceptability criteria should include the two types of acceptability criteria: operational requirements and fidelity requirements. The operational requirements are "non-analytical" requirements that do not directly contribute to the resolution of program decisions. Operational requirements define hardware and software compatibility requirements; pre- and post-processing requirements for M&S; operations and training support requirements; etc. Fidelity requirements define how well required M&S functions must correspond to the "real world" in order for the M&S outputs to be considered acceptable for the intended use.*

7. Proposed Accreditation Methodology. *Describe the overall accreditation effort, emphasizing technical tasks to be performed, and the impact of any known limitations or constraints that may affect a complete evaluation of the M&S application (for example, insufficient resources, unavailable or out-of-date documentation). Of utmost importance is a description of the steps or process used to assess whether the acceptability criteria have been adequately met to determine appropriateness of the M&S to the application. Because accreditation will constitute a qualitative assessment, it must be convincing and it must provide the decision-maker with a relatively high degree of confidence in the recommendation.*

APPENDIX H

ACCREDITATION REPORT CONTENTS

H-1. The accreditation report must be written in a manner that will allow it to be read and understood as a stand-alone document. Although references to other VV&A plans and reports may be made as necessary, full understanding of the accreditation report must not rest upon the premise that the reader has a detailed understanding of them.

H-2. The format and a detailed description of the contents of each paragraph of the Accreditation Report follow:

1. Executive Summary. *Briefly describe the adequacy of the supporting documentation and configuration control. Clearly convey all evidence that the M&S will perform as advertised and that it is appropriate for this class of applications or for this specific application. State also the recommendations for the M&S based on the information given.*

a. Overall Issues and Findings. *Include the overall issues and findings of the accreditation process for the M&S.*

b. Strengths and Limitations. *Highlight the M&S strengths and limitations, especially in terms of the intended use.*

c. Identification of Agencies. *Identify agencies/personnel responsible for performing the accreditation.*

d. Recommendation. *Recommendations should consist of a statement that explicitly approves or rejects use of the M&S based on the information in the sections above. In cases where all acceptability criteria were not used as a basis for judgment, all ramifications of proceeding with this application should be stated in qualitative terms. This statement is based on the M&S application sponsor's degree of confidence in or the credibility of the results of the M&S in this application.*

2. Acceptability Criteria. *This section should describe each criterion, how and why each was established, and how the degree of satisfaction of these criteria was assessed. This section should correspond with its counterpart in the accreditation plan. If there is any deviation, it should be so stated and the reason explained. Information on each criterion chosen should include:*

- *Description of the criterion.*
- *Any possible ratings. Give a brief description of the reason for the rating. This may be subjective and should describe the M&S capability or limitations under this criterion.*
- *Summarize why this item is important for the intended use of the M&S. Include some degree of criticality of the item.*

APPENDIX I

GLOSSARY

Section I
Acronyms

ACAT - Acquisition Category

ADS - Advanced Distributed Simulation

AMSAA - U.S. Army Material Systems Analysis Activity

AR - Army Regulation

C4I - Command, Control, Communications, Computers and Intelligence

CAD - Computer Aided Design

CAM - Computer Aided Manufacturing

CDR - Critical Design Review

CI - Configuration Item

CM - Configuration Management

CPU - Central Processing Unit

CSCI - Computer Software Configuration Item

DA - Department of Army

DIS - Distributed Interactive Simulation

DMSO - Defense Modeling and Simulation Office

DOD - Department of Defense

DODD - Department of Defense Directive

ECP - Engineering Change Proposal

FCA - Functional Configuration Audit

FQR - Formal Quality Review

HITL - Human-in-the-Loop

HLA - High Level Architecture

HW - Hardware

HWCI - Hardware Configuration Item

HWIL - Hardware-in-the-Loop

IEEE - Institute of Electrical and Electronic Engineering

IV&V - Independent Verification and Validation

M&S - Modeling and Simulation

PCA - Physical Configuration Audit

PDL - Program Design Language

PDR - Preliminary Design Review

SIMNET - Simulation Network

SLOC - Source Lines of Code

SME - Subject Matter Expert

SDR - System Design Review

SRR - System Requirements Review

SSR - Software Specification Review

STEP - Simulation, Test, and Evaluation Process

SUT - System Under Test

T&E - Test and Evaluation

DTC - U.S. Army Developmental Test Command

TRAC-WSMR - U.S. Army Training & Doctrine Command Analysis Center - White Sands Missile Range

TRR - Test Readiness Review

VPG - Virtual Proving Ground

V&V - Verification and Validation

VV&A - Verification, Validation, and Accreditation

VV&C - Verification, Validation, and Certification

WBS - Work Breakdown Structure

Section II
Terms

Acceptability Criteria
A set of standards that a particular M&S must meet to be accredited for a given use.

Accreditation
An official determination by management that an M&S is acceptable for a specific purpose.

Accreditation Process
The procedure followed by the M&S application sponsor that culminates in the accreditation determination.

Accreditation Proponent
(1) The agency designated to determine if an M&S is acceptable for a generic class of applications; or (2) the sponsor of a specific application involving the use of an M&S.

Allocated Baseline
The initially approved documentation describing an item's functional, interoperability, and interface characteristics that are allocated from those of a system or a higher level CI, interface requirements with interfacing CIs, additional design constraints, and the verification required to demonstrate the achievement of those specified characteristics.

Allocated Configuration Documentation
The approved allocated baseline plus approved changes.

Application Sponsor
The agency that utilizes the results/products/output from a specific application of M&S.

Baseline
Configuration documentation formally designated during a CI's life cycle. Configuration baselines, plus approved changes from those baselines, constitute the currently approved configuration documentation. There are three formally designated configuration base-lines in the life cycle of a CI, namely the functional, allocated, and product baselines.

Configuration
The functional and physical characteristics of existing or planned hardware, firmware, software or a combination thereof as set forth in technical documentation and ultimately achieved in a product.

Configuration Control
The systematic proposal, justification, evaluation, coordination, approval or disapproval of proposed changes, and implementation of all approved changes, in the configuration of a CI after establishment of the configuration baseline(s) for the CI.

Configuration Documentation
The technical documentation that identifies and defines the item's functional and physical characteristics. The configuration documentation is developed, approved, and maintained through three distinct evolutionary, increasing levels of detail. The three levels of con-figuration documentation are the functional configuration documentation, the allocated configuration documentation, and the product configuration documentation.

Configuration Item
An aggregation of hardware or software that satisfies an end-use function and is designated for separate configuration management.

Configuration Management
The application of technical and administrative direction and surveillance to identify and document the functional and physical characteristics of an M&S, control changes, and record and report change processing and implementation status.

Configuration Management Plan
The document that defines how configuration management will be implemented (including policies and procedures) for a particular program.

Constructive Simulation
Systems of this type involve real people making inputs into a simulation that carries out those inputs by simulated people operating simulated systems. Simulations of this class typically build or construct a model over a period of time that is less than, equal to, or greater than real time. This technique is particularly valuable in building simulations of events which occur over very long time periods (weeks, months, or years) or over very short time periods (milliseconds or less). Once a simulation run is completed, the output data can be manipulated with data viewing and analysis tools to precisely isolate events at different points in simulation time.

Data Certification
Baseline data approval process.

Data Validation
Review of the data to compare them to the corresponding, known real world or best-estimate values.

Data Verification
Review of the data values to ensure they are converted and formatted properly for input into the M&S and are consistent with M&S concept and logical design.

Developing Agency
The agency which actually develops an M&S. The developing agency and the sponsoring agency may be the same.

Distributed Interactive Simulation
Any combination of virtual, constructive, and live simulations that are distributed over a network and interact through standard protocols.

Distributed Simulation
A simulation of this class consists of multiple executable applications executing on one or more CPUs physically or logically distributed over a digital network. Common distributed M&S architectures include DIS, HLA, and various tactical standards used within the DOD. The most immediately recognizable trait of a distributed simulation is its reliance on a digital telecommunications network for transfer of information between its various simulation components.

Documentation Review
The collection and review of any existing documentation of an M&S to ensure logical consistency with current documentation efforts.

Fidelity
The degree to which aspects of the real world are represented in the M&S.

Functional Baseline
The initially approved documentation describing a system's or item's functional, inter-operability, and interface characteristics and the verification required to demonstrate the achievement of those specified characteristics.

Functional Configuration Audit

The formal examination of functional characteristics of a CI, prior to acceptance, to verify that the item has achieved the requirements specified in its functional and allocated configuration documentation.

Functional Configuration Documentation
The approved functional baseline plus approved changes.

Independent Reviewer (or Independent V&V agent)
An outside agency or contractor (usually individuals or an agency that did not develop the M&S) responsible for the accomplishment of verification and validation activities of an M&S. IV&V do not require complete organizational independence, but a reasonable degree of organizational separation should be observed to assure unbiased analysis.

Intended Use
The application, experiment of study for which the model has been proposed or chosen as a tool.

Live Simulations
Systems of this type involve real people operating real systems. A live simulation contains minimal simulation components. It consists of an instrumented live entity that can participate in a multi-player simulation scenario as if it were part of the virtual environment. Live simulations typically contain sensor and/or display systems and a data transmission system. The sensor system captures salient entity parameters in data that are passed to the data transmission system that couples the data into a computer simulation. If one exists, the display system allows the live entity to visualize some portion of the virtual battle space and be stimulated by its live and virtual entities and other environ-mental features. Live simulation systems are most commonly employed in distributed battlefield simulations where actual participation of live forces in an otherwise virtual event is desirable or for real time visualization of on-going hardware tests. Like virtual simulations, the outcome of a live simulation is not repeatable due to the nature of human behavior.

M&S Developer
The agency which actually develops an M&S or the agency that is overseeing the M&S development by a contractor or Federally Funded Research and Development Center.

M&S Proponent
The agency or organization that has primary responsibility for M&S in its area of interest.

M&S User
Those who apply M&S to specific applications.

Model
A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

Modeling and Simulation
The use of models, including emulators, prototypes, simulations, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms “modeling” and “simulation” are often used interchangeably.

Output Validation

The process of determining the extent to which the output (outcome distributions for the M&S and/or sub-models) represents the significant and salient features of distributions or real world systems, events, and scenarios.

Physical Configuration Audit

The formal examination of the "as-built" configuration of a CI against its technical documentation to establish or verify the CI's product baseline.

Product Baseline

The initially approved documentation describing all of the necessary functional and physical characteristics of the CI and the selected functional and physical characteristics designated for production acceptance testing and tests necessary for support of the CI. In addition to this documentation, the product baseline of a CI may consist of the actual equipment and software.

Product Configuration Documentation

The approved product baseline plus approved changes.

Process Model

A model of the processes performed by a system; for example, a model that represents the software developmental process as a sequence of phases.

Prototype

A preliminary type, form, or instance of a system that serves as a model for later stages or for the final, complete version of a system.

Reference Version

The most recent version of an M&S which has been released for community use by and under configuration management of the M&S users group executive committee.

Resolution

The degree of detail and precision used in the representation of real world aspects in the M&S.

Simulation

A method for implementing a model or models over time.

Sponsoring Agency

The agency which sponsors the development or use of M&S utilizing either in-house, other government agency, or contract resources.

Synthetic Environment

Representation of the test ranges, facilities, background, and conditions in which the item-under-test is to operate.

Synthetic Stimuli

Presentation of signals (targets, signatures, network messages, etc.) to a sensing device of the item-under-test to imitate the effects of the system.

Stimulator
(1) A hardware device that injects or radiates signals into the sensor system(s) of operational equipment to imitate the effects of platforms, munitions, and environment that are not physically present; (2) a battlefield entity consisting of hardware and/or software modules which injects signals directly into the sensor systems of an actual battlefield entity to simulate other battlefield entities in the virtual battlefield.

Structural Validation
The process of determining that the M&S assumptions, algorithms, and architecture provide an accurate representation of the composition of the real world as relevant to the intended use of the M&S.

Validation
The process of determining the extent to which an M&S is an accurate representation of the real world from the perspective of the intended use of the M&S.

Verification and Validation Proponent
The agency responsible for ensuring V&V is performed on a specific model or simulation.

Verification
The process of determining the extent to which an M&S is an accurate representation of the real world from the perspective of the intended use of the M&S. Verification evaluates the extent to which the M&S has been developed using sound and established system engineering techniques.

The proponent of this pamphlet is the Technology Management Division (Directorate for Test and Technology). Users are invited to send comments to Commander, DTC, ATTN: CSTE-DTC-TT-M, Aberdeen Proving Ground, Maryland 21005-5055.

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