V&V Agent Role in the VV&A of Legacy Simulations

RPG Core Document

4 August 2004

Table of Contents

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Table of Contents continued

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Overview

What is the Role of the V&V Agent in Legacy Simulation VV&A?

This document describes the role and responsibilities of the V&V Agent in the verification, validation, and accreditation (VV&A) of a legacy simulation.[1] ***V&V Agent*** is the term used throughout the RPG to describe the organization, group, or person responsible for performing V&V activities. In the home-buying analogy presented in the Key Concepts, the V&V Agent represents all the specialty inspectors engaged to ensure that different aspects of the house are functioning properly.[2]

Other roles that perform and support legacy simulation VV&A include

- **User** – the role responsible for defining the problem (e.g., M&S requirements, measures, acceptability criteria, referent), determining how to solve it, and making the accreditation decision
- **Accreditation Agent** – the role responsible for conducting the accreditation assessment
- **M&S Program Manager** – the role responsible for managing the modification of the simulation for the intended use, when needed
- **Developer** – the role responsible for providing technical expertise regarding simulation capabilities, for preparing data for use in the simulation, and for making code modifications and developing new code, when needed
- **M&S Proponent**– the role responsible for managing the legacy simulation throughout its lifecycle, including configuration management, application, and maintenance, and for approving all modifications to the authorized version of the simulation[3]

These roles can be filled in a variety of ways, such as

- each role performed by a different individual, group, or organization
- several roles performed by the same individual, group, or organization
- all the roles performed by the same individual, group, or organization

[1] Throughout this document the term *simulation* is used to denote either a model or a simulation and the term *legacy simulation* is used to denote a model or simulation that has been used previously or was developed for a different application.
[2] See the RPG menu item, VV&A Key Concepts, for additional information.
[3] Note that the M&S Proponent role is responsible to the simulation program.

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The number of performers required for a given application is predicated on the needs of the application, the amount of work required in each role, the availability of resources, and the risks involved. When extensive simulation modifications are needed or when the issues being addressed involve critical concerns (e.g., health, safety), it is more likely that a specific individual or group will be designated for each role. When a legacy simulation is well documented, has been used for similar applications in the past, and requires little or no modification, some roles may be performed by the same individual or group. For example, the V&V tasks may be performed by the User or Accreditation Agent in lieu of employing a separate V&V Agent.

In any case, the fundamental role of the V&V Agent is to provide evidence of the simulation's fitness for the intended use by collecting available information, validating the simulation for the user's purpose, and ensuring all other V&V tasks are properly performed.

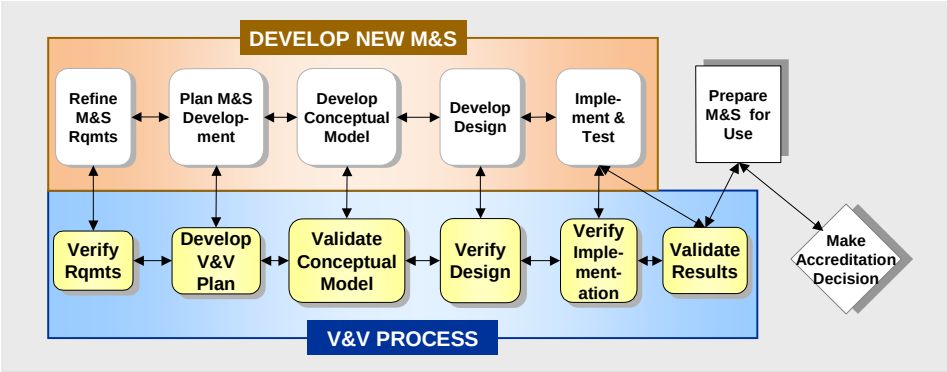
How Does This Differ from the V&V Agent Role in New Simulation?

Considerable similarity exists between the V&V Agent roles in legacy and new simulation VV&A. In both situations, the V&V Agent focuses on the same basic functions: verifying that the M&S requirements are consistent and conform to the user's needs, validating the conceptual model, verifying that the design and implementation conform to the validated conceptual model, and validating the simulation results. In both situations, the V&V Agent will use many of the same techniques and perform many of the same tasks. The fundamental differences arise in the responsibilities associated with the V&V Agent role, how and when different tasks are performed, the relative importance of different activities, how the information is acquired and assembled, and the challenges involved.

In the V&V effort for a new simulation, the initial focus is to gain a thorough understanding of how the simulation is being developed to address the User's requirements.[4] The V&V effort complements the development effort. The V&V Agent knows what information will be available and where it can be obtained. The V&V activities are coordinated with development activities to ensure development artifacts are assessed in a timely manner, as illustrated in the following figure.

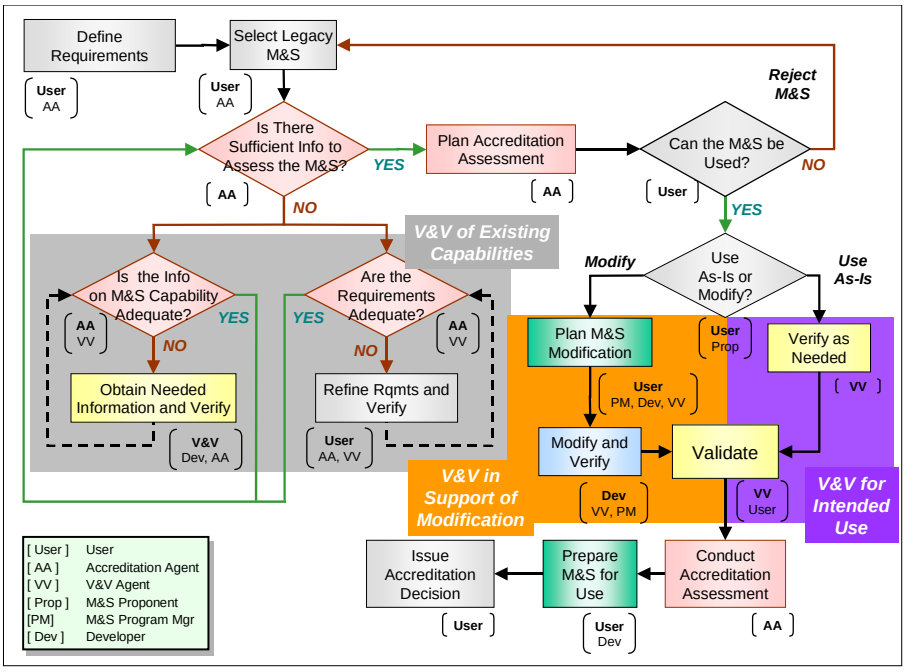
In addition, those responsible for the development of the simulation—the User defining its requirements, the Developer building it, and the M&S PM managing its development—are accessible to the V&V Agent. Problems can be resolved in a variety of ways, through changes in the simulation design, simulation implementation, or in the requirements to be addressed.

[4] See the core document on the V&V Agent Role in the VV&A of New Simulations for additional information.



Interaction Between V&V and New Development Activities

In legacy simulation reuse, there is no development effort to respond to so the VV&A effort is conducted as the series of events described in the *VV&A of Legacy Simulation Overview* and illustrated in the following flow diagram.



V&V Activities in Legacy Simulation VV&A

The V&V activities involved fall into three categories:

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- **those assessing existing simulation capabilities**. Early V&V activities focus on establishing the relationship between the intended use and the selected simulation. They lay the foundation for subsequent V&V activities which and are conducted regardless of whether the simulation is modified.
- **those assessing the simulation for the intended use**. These V&V activities focus on providing the information needed to assess the fitness of the simulation for the intended purpose. In general, they are conducted regardless of whether modification is involved.
- **those supporting the simulation's modification**. These activities focus on ensuring that the modifications are adequate to address the identified limitations.

These categories, shown highlighted in grey, purple, and orange, respectively, in the flow diagram [p. 3], are used to organize the discussion of V&V Agent responsibilities and functions in the remainder of this document.

VV&A Responsibilities of the V&V Agent Role

The V&V effort should focus on meeting the accreditation information needs. These identify the information necessary to perform an adequate accreditation assessment and these needs determine the nature, scope, and depth of the V&V effort. They include the M&S requirements and their associated acceptability criteria, the risks associated with using the simulation to address the intended use, and the priorities established by the Accreditation Agent. The priorities determine the order in which the M&S requirements should be addressed and their relative importance to the intended use. When V&V funding is limited, they allow the V&V Agent to focus V&V activities on those parts of the simulation most critical to the User's purpose.

Conducting an effective V&V effort requires the V&V Agent to understand several things about the legacy simulation and the User's purpose:

- assumptions underlying the simulation's design for both the existing and modified simulation
- representational capabilities and limitations for both the existing and modified simulation
- data that the simulation requires for execution, its nature, and its impact on the simulation results
- representational implications of the simulation's execution environment
- simulation performance in previous, similar applications
- simulation representations that are key drivers for the intended purpose
- sensitivity of critical simulation representations to variations in input data

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- representations required to achieve the intended purpose (e.g., problem statement, M&S requirements, acceptability criteria, referent)
- acceptable tolerances on the accuracy of the simulation performance and results

The table below lists the typical V&V Agent responsibilities associated with different functions involved in the V&V of a legacy simulation. They are grouped into the three basic activity sets illustrated in the Legacy Simulation VV&A flow diagram [p. 3]

Activities	Function	Typical V&V Agent Responsibilities
Assessing Existing Capabilities	Collect Simulation Information [p. 10]	• collect and review available simulation documentation, VV&A history, and use history ensuring the available documentation is relevant to the intended use • generate essential missing information as needed • use knowledge of information to support simulation selection and identify simulation capabilities and deficiencies
Assessing Existing Capabilities	Support Legacy Simulation Selection [p. 11]	• summarize the capabilities of each simulation candidate • summarize the information from prior relevant accreditations • review information about each candidate for correctness, sufficiency and consistency
Assessing Existing Capabilities	Assemble the Referent [p. 13]	• identify credible referent information sources • characterize the referent's scope • collect referent information • combine information into a single coherent referent
Assessing Existing Capabilities	Verify M&S Requirements [p. 13]	• understand the M&S requirements of the intended application and their associated measures and acceptability criteria • identify and assemble the simulation referent • verify requirements for completeness and consistency • establish traceability of M&S requirements to objectives • evaluate the adequacy and consistency of the scenarios • document the requirements verification activities
Assessing Existing Capabilities	Characterize Simulation Capabilities [p. 17]	• evaluate the consistency and completeness of the existing information about the simulation capabilities • collect additional information, if needed, through testing or reverse engineering • assemble simulation information into an integrated picture of simulation capabilities

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Activities	Function	Typical V&V Agent Responsibilities
Assessing Existing Capabilities	Identify Simulation Inadequacies [p. 17]	• validate existing simulation against the referent • identify unmet requirements • identify simulation incompatibilities
Assessing Simulation for Intended Use	Develop V&V Plan [p. 19]	• assess V&V risks • select V&V tasks to address the accreditation information needs and priorities and to meet cost and schedule constraints • coordinate V&V tasks with simulation and accreditation activities • tailor the V&V plan as needed • document the V&V planning activities
Assessing Simulation for Intended Use	Verify As Needed [p. 27]	• conduct V&V tasks as needed for the intended application
Assessing Simulation for Intended Use	Verify and Validate Data [p. 27]	• evaluate simulation data needs • verify data sources and data availability • verify databases and metadata • verify data transformations from source through input • validate methods used in data transformations • validate input data • verify output data specifications
Assessing Simulation for Intended Use	Validate Simulation Results [p. 30]	• map the integrated tests to the requirements • conduct validation testing • validate the required representations • adjudicate any errors encountered during validation testing
Assessing Simulation for Intended Use	Document V&V Effort [p. 34]	• document results of V&V activities • collect and record information on all V&V activities • prepare the V&V report and submit it to Accreditation Agent • prepare and submit V&V information for inclusion in the simulation configuration management system
Providing Modification Support	Trace M&S Requirements [p. 35]	• ensure M&S requirements map to simulation artifacts, software, and tests • review the modified conceptual model to ensure its traceability to the M&S requirements • map capabilities represented in the modified designs back to the conceptual model

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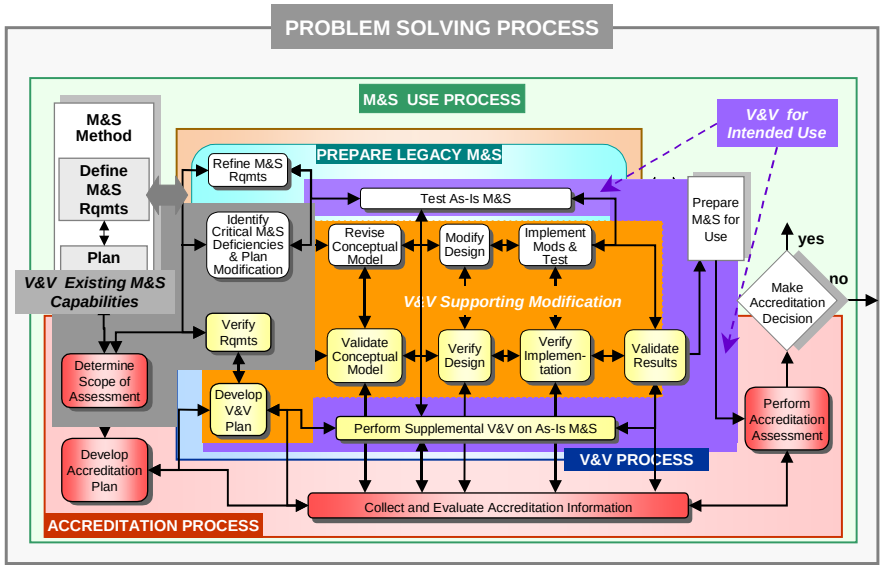
Activities	Function	Typical V&V Agent Responsibilities
Providing Modification Support	Validate Conceptual Model [p. 36]	• assess adequacy of the modified conceptual model • ensure conceptual model addresses the M&S requirements of intended application • evaluate scenario(s) and timelines • compare simulation capabilities against requirements • document conceptual model validation activities
Providing Modification Support	Verify Design [p. 40]	• assess the algorithms employed in the modifications • verify that the design artifacts support the functionality described in the conceptual model • verify the test plans • document the design verification activities
Providing Modification Support	Verify Implementation [p. 42]	• verify that the software addresses the functionality described in the conceptual model • verify that the hardware configuration and implementation support the software functionality and the functionality described in the conceptual model • verify the consistency of the software to hardware mapping • verify tests and their results • document the implementation verification activities

VV&A Functions of the V&V Agent Role

In the Overall Problem Solving Process described in the *RPG VV&A Key Concepts*, the legacy simulation subprocess begins with the User's decision to use a legacy simulation. From the moment this decision is made, the V&V Agent can play a crucial role. As illustrated in the legacy simulation VV&A flow diagram [p. 3], the V&V Agent role in legacy simulation can be grouped into three phases.

- Assessing Existing Simulation Capabilities [p. 8]
- Assessing the Simulation for the Intended Use [p. 18]
- Providing Support for the Modification Effort [p. 34]

These phases, shown superimposed on the Overall Problem Solving Process diagram on page 8, are used to organize this discussion of the functions of the V&V Agent role because they separate the functions into those that are normally performed from those that are normally performed only when simulation modification is involved.



V&V in the Legacy Simulation Process

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Assessing Existing Simulation Capabilities

Once the decision has been made to use legacy simulation, questions should be asked about the existing capabilities[5] of the simulation selected (or the candidates under consideration). Only by knowing what the simulation (or candidate) brings with it, in terms of capabilities and limitations, can the User determine what needs to be done to ensure the simulation is fit for the intended purpose.

When more than one candidate is under consideration, the User, working with the Accreditation and V&V Agent, determines which is the most appropriate by assessing their capability, usability, and affordability. Once a simulation has been selected, the User works with the Accreditation Agent and V&V Agent to assess how well that simulation can address the M&S requirements and to identify what should be done, if anything, to improve the simulation's fitness for the intended use. This begins with the Accreditation Agent and, possibly, the V&V Agent iteratively refining and verifying the M&S requirements and identifying what simulation capabilities are needed to satisfy each.

At the same time, the V&V Agent works with the Accreditation Agent and, possibly, one or more former developers, to characterize the legacy simulation's capabilities. With detailed and verified M&S requirements and sufficient description of the simulation's representational capabilities, the V&V Agent can validate the unmodified simulation for

[5] "Existing" refers the state of the simulation (or simulation candidate) when it is provided for use (or consideration); i.e., before anything has been done to prepare it for the intended use.

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the User's purpose. This information permits the Accreditation Agent to recommend the activities that need to follow in order to prepare the simulation for the new use. This preparation may involve modifying the chosen simulation, choosing a new simulation or just using the simulation as is. In any of these cases, this recommendation permits the V&V Agent to plan the rest of the V&V effort.

V&V functions supporting this effort include

- Collect Simulation Information [p. 10]
- Support Simulation Selection [p. 11]
- Assemble Validation Referent [p. 13]
- Verify M&S Requirements [p. 13]
- Characterize Simulation Capabilities [p. 17]
- Identify Simulation Inadequacies [p. 17]

Collect Simulation Information

Simulation information should be obtainable from the M&S Proponent as the simulation's configuration manager. If the simulation has been under configuration management, up-to-date artifacts (e.g., conceptual model, designs) and documentation should be readily available. However, if the simulation has not been maintained under centralized configuration control, when multiple versions of the simulation exist, then the V&V Agent may need to seek alternative sources.

The V&V Agent should start by identifying what information is available about the simulation (or simulation version) being considered for use (e.g., applicable V&V history, simulation documentation, user reports). Ideally, historical V&V information is kept with other information about the simulation under configuration control. However, when this is not the case, or if the information available is not sufficient to provide a clear and complete understanding of the simulation version involved, the V&V Agent may need to interview previous Users, piece together change histories and records, assess and correct key documents. See Appendix A for additional information.

The V&V Agent should also examine the simulation's configuration management system and determine whether the historical V&V information can be unambiguously associated with a particular version. If the simulation has undergone a number of revisions since it was first put into service, and if available V&V documentation is not unambiguously correlated to particular versions, then such information may be of only marginal value except as a general indicator of the scope and depth of V&V activities typically applied to modifications to the simulation.

When necessary information cannot be found, the V&V Agent should work with the Accreditation Agent to determine how best to supply the information and include these activities in the V&V plan. The V&V Agent may need to generate it using regression

testing, reverse engineering, or by conducted additional V&V tasks. In regression testing, the simulation is executed using various scenarios (scenarios and test data used previously if possible) and information characterizing simulation capabilities or demonstrating simulation limitations is extracted from the results. In reverse engineering, information about simulation's capabilities is extracted from an examination of the software source code and data metadata.[6] When additional V&V tasks or testing are needed, the V&V Agent should emulate previous efforts using the same test data and constructs when possible.

The need to collect legacy simulation information continues throughout the V&V effort.

- The information that was adequate to use during simulation selection [p. 10] may not be sufficient to characterize simulation capabilities [p. 16] well enough to determine if modification will be needed. The conceptual model is an excellent source of information on the entities, characteristics, and behaviors represented in the simulation.[7] If there is no formal conceptual model, this information should be compiled from existing documents (e.g., requirements specification, design documentation, testing results, VV&A history) and then verified. For information on simulation limitations and also on methods used to overcome them, the V&V Agent should interview previous Users and Developers.
- When the simulation does require modification to meet the User's needs, the V&V Agent will need additional information about the existing software and hardware to ensure that the modifications perform properly and do not create problems for the existing functionality. The amount of legacy software that the V&V Agent needs to understand is a function of the internal construction and architecture of the simulation, the resources available, the scope of the modification effort (if any), and the amount of risk that is acceptable to the User.

The V&V Agent should also ensure that simulation information is collected about the simulation throughout its preparation and use in the intended application. If the simulation's configuration management process includes an information archive, the V&V Agent should ensure that the information is retained in compatible forms. If such an archive does not exist, the V&V Agent should establish one for the information collected.

Support Simulation Selection

During the analytic and decision-making activities that dominate the early phases of the Problem Solving Process,[8] the User may face more than one possible choice of legacy simulations to use.[9] Each of these candidates should be carefully assessed to identify the one the best meets the User's simulation needs. This choice can dramatically affect

[6] See the reference document on Data V&V Concepts and Terms for additional information.
[7] See the special topic on Conceptual Model Development and Validation for additional information.
[8] See the RPG diagram, Overall Problem Solving Process and the Key Concepts for additional information.
[9] See the core document on the User Role in the VV&A of Legacy Simulations for additional information.

the cost and effort required to prepare the simulation for a new use as well as the effectiveness with which that simulation serves the User's purposes. Clearly differentiating the strengths and weaknesses of each candidate can greatly improve the quality of this very important decision.

This assessment process may require considerable information about each candidate simulation and about the M&S requirements of the intended use.[10] Information useful to this endeavor is shown in the following table.

Information Used in Simulation Selection
• Simulation conceptual model
• Assumptions, limitations, and known errors
• Unresolved design and implementation issues
• Simulation verification methods and results
• Past uses and the validation information associated with those uses
• Implementation information, such as its source language, software size and execution environment requirements
• Data requirements
• Existing databases and their validation documentation
• Simulation availability
• Existing support infrastructure (e.g., help desks, onsite maintenance)
• Amount and quality of user documentation
• User training requirements
• Past user experiences with using the simulation and its support infrastructure
• Configuration management history (including the change request database)
• Development history

If the information is not readily available, in comparable formats and at sufficient levels of detail, then the V&V Agent may be assigned the task of gathering and supporting the assessment of the information needed.[11] This comparison of simulation capabilities is essential in helping the User select the best simulation to use in the intended application. In addition, much of the information gathered about the simulation selected will be needed to support its validation.

One of the most important items in this table [p. 11], and perhaps the most difficult to obtain, is a list of assumptions, limitations, and known errors. These may be recorded and/or inferred from documentation from prior accreditation(s) of the simulation.

[10] See the special topic on Requirements for additional information.

[11] Although the V&V Agent may be designated by this time, this is not normally the case, and the V&V tasks supporting this activity are performed by others. The V&V Agent may not be designated until the Accreditation Agent has determined the scope of the accreditation assessment effort that, in turn, helps determine the scope of the V&V effort.

> Example:
>
> A previous accreditation report for one candidate simulation lists as a constraint, "cannot be used for over-the-horizon radar detections." Upon investigation, it is learned that the candidate simulation was developed to calculate range at radar detection, and assumes flat earth.

See Appendix B for additional information on simulation selection.

Assemble the Referent

Identifying and assembling the referent is one of the earliest tasks for the V&V Agent. A ***referent*** is a *codified body of knowledge about a thing being simulated* [RPG Glossary]. The referent defines the standard against which to measure the accuracy of the simulation's representations. In simulation, ***accuracy*** is the *fidelity of the representations; quality and precision of the input data; how closely the results correspond to the intended view of reality* [RPG Glossary]. Representational accuracy cannot be meaningfully specified and its validity for a specific purpose cannot be assessed without a referent.

Referents can come in many forms, such as the results of experiments, theory developed from experiments, validated results from other simulations, and expert knowledge obtained through research or from subject matter experts (SMEs).[12] The M&S requirements define the scope of a simulation's referent by specifying the properties (e.g., characteristics, behaviors) for which minimum accuracies are needed to adequately serve the purpose. Acceptability criteria that stipulate accuracy constraints should also define the value ranges over which those constraints apply.

The V&V Agent should choose a referent that best represents the things being simulated and that has the most credibility to the User. Ideally, the User specifies the referent that they prefer. However, if not, the V&V Agent should examine all of the sources of knowledge about the subject to be simulated and compare them against the acceptability criteria to assess their appropriateness. When appropriate referents have been identified then their credibility to the User should be determined. From this, the most appropriate and credible combination of referents should be chosen.

[12] See the special topic on Subject Matter Experts and VV&A for additional information.

Verify M&S Requirements

M&S requirements define the capabilities that the legacy simulation needs in order to adequately support the intended use.[13] Paramount among these are the ***representational requirements***, which define what entities and behaviors need to be simulated and how they need to be represented (e.g., characteristics, interactions, levels of detail), to adequately serve the intended use. In legacy simulation reuse, these M&S requirements may or may not correspond to the requirements that the legacy simulation has addressed in its previous uses.

During requirements verification, the V&V Agent ensures the M&S requirements provide sufficient detail to provide a complete picture of what simulation capabilities are needed to address the intended use and to assess the adequacy and correctness of the legacy simulation representations (entities, characteristics, behaviors) for the intended use.

Because subsequent V&V activities depend to a great extent on the completeness and consistency of the M&S requirements, requirements verification should be done as early as possible and may be undertaken by the User or Accreditation Agent when no V&V Agent has been designated. Since requirements are often enhanced, clarified, or refined as time passes, the V&V Agent should be prepared to conduct additional verification activities as needed.

The basic tasks associated with requirements verification are listed below and discussed in the following sections. The priority of each task depends upon the priorities of the accreditation assessment, the completeness and refinement of the M&S requirements, and the type and magnitude of the modification (if any) involved.

- Establish Requirements Tracing [p. 14]
- Verify Requirements Consistency [p. 15]
- Evaluate Adequacy of Scenarios [p. 16]
- Document Requirements Verification Activities [p. 16]

Requirements tend to evolve. Changes in the User's needs often result in changes to the M&S requirements and their associated acceptability criteria. As changes occur, the M&S requirement set, should be revisited to ensure new and altered M&S requirements are verified and the set as a whole remains consistent, necessary and sufficient.

Requirements verification frequently relies upon SME judgment but may employ different analysis techniques. The use of sophisticated techniques and tools (such as formal requirements representations [e.g., special grammars], mathematically-based verification techniques [e.g., predicate logic] or automated support [e.g., automated consistency checkers]) can help make requirements verification feasible and practical,

[13] See the special topic on Requirements for additional information.

particularly for projects involving large M&S requirement sets and complex acceptability criteria.[14]

Establish Requirements Tracing

Requirements tracing is performed to ensure the M&S requirement set is complete and the individual M&S requirements are adequately addressed by the simulation concept, design, and implementation. In particular, when modification is involved, requirements tracing helps ensure that the M&S requirements are adequately addressed in the modified simulation artifacts (e.g., modified conceptual model, design documents, code).

Initially, M&S requirements are traced to the User needs and objectives of the intended application to ensure the set is complete and the M&S requirements are both necessary and sufficient for the intended application. In particular, the V&V Agent verifies that

- the User needs and objectives of the intended application are adequately addressed by the M&S requirements
- all M&S requirements address (map to) User needs and objectives
- refined or derived requirements address (map to) other M&S requirements of the intended application

Requirements tracing continues throughout the V&V process to ensure the M&S requirements are adequately addressed in the simulation artifacts and simulation. If simulation artifacts are modified or developed during the modification effort, this task is be revisited to ensure the M&S requirements can be mapped to the artifacts; when test plans have been drafted, this task is revisited to ensure the M&S requirements can be mapped to the tests (see *Trace M&S Requirements* [p. 35]).

One method for capturing and maintaining this information is through the use of a requirements tracing matrix or database. If the legacy simulation has an existing requirements tracing matrix that is available for use, it can be used to determine if the M&S requirements of the intended application are already adequately addressed in the simulation. The matrix should be reviewed to determine if it contains requirements that correspond to the M&S requirements of the intended use (e.g., the requirement definition and associated measures and acceptability criteria in the matrix are comparable to those of the M&S requirement and links to simulation artifacts indicate appropriate treatment within the simulation). M&S requirements of the intended application that are not contained in the existing matrix can then be added.

If a requirements tracing matrix or database does not exist, then one should be developed for the intended use. This is particularly useful when the legacy simulation is to be modified.[15] A requirements tracing matrix or database should provide descriptions

[14] See the reference documents on V&V Techniques and V&V Tools for additional information.
[15] The Developer may establish one for use in the modification effort. If not, the V&V Agent should do so.

of each M&S requirement, and its associated measures and acceptability criteria, as well as information on its source (e.g., its mapping to User needs, objectives and other M&S requirements) and information on how it is addressed in the simulation and simulation artifacts. The verification of the correctness and completeness of the information in this database is a key V&V activity. The V&V Agent should ensure that each M&S requirement is appropriately recorded

Verify Requirement Consistency and Completeness

Consistency and completeness are necessary to ensure the M&S requirement set provides a clear and unambiguous statement of the intended use. The representational requirements should be reviewed by the V&V Agent and SMEs from the user and problem domains associated with the intended use. They examine the requirements to ensure they are individually, and as a set, sufficient to address the intended use.

Consistency and Completeness Issues to be Addressed
• are any aspects of the intended use not adequately addressed by the requirements (i.e., are there any gaps in the requirement set)?
• are any requirements in conflict?
• is each requirement adequately defined, to include the characteristics, behaviors, fidelity expected?
• is the fidelity of each requirement appropriate for the intended use?
• are the characteristics and behaviors specified in each requirement description sufficient for the intended use?
• is each requirement measurable (i.e., types of measures (e.g., MOEs, MOPs)?[16]
• are the measures appropriate and adequate? can the data needed for the measures be collected from the simulation?
• is each requirement properly delimited by its associated acceptability criteria (i.e., do the acceptability criteria address all the aspects of the requirement that need to be simulated: is the level of acceptance established for each appropriate for the intended use)?

The V&V Agent should be supported by the Developer and software and hardware experts to verify any requirements associated with the simulation domain to ensure they are adequate and sufficient for the intended use and also compatible with the legacy simulation. Some of the issues to be considered are listed in the following table.

Simulation-Related Consistency Issues
• is each such requirement appropriate and necessary for the intended use?
• are any such requirements incompatible with each other?
• can each such requirement be accommodated by the legacy simulation?
• what is the impact of implementing each such requirement on the simulation?

[16] See the special topic on Measures for additional information.

Simulation-Related Consistency Issues
• what is the impact of not implementing each such requirement on the intended use?

In verifying individual M&S requirement consistency, the V&V Agent should verify its associated acceptability criteria by checking each acceptability criterion for reasonableness and testability and checking the set of associated criteria for

- **internal conflicts** -- where achieving one criterion makes achieving another impossible
- **internal completeness** -- achieving one criterion requires achieving others that have not been described
- **redundancy** -- two or more criteria describe the same capability

Once these issues have been addressed, the verified acceptability criteria should be submitted to the User for confirmation that they adequately and efficiently serve the intended use. Although this is a responsibility of the Accreditation Agent, the V&V Agent may be asked to assist in preparing the information. Similarly, the Accreditation Agent may also seek the V&V Agent's assistance in deriving detailed acceptability criteria from the User's objectives and M&S requirements.

The V&V Agent may also assume responsibility for or contribute to the development of the requirements tracing matrix, discussed in *Establish Requirements Tracing* [p. 14], that captures the relationships between the M&S requirements and the formal acceptability criteria against which the simulation capabilities will be measured.

Evaluate the Adequacy of Scenarios

Scenarios serve to "bound the problem." Each proposed scenario should be evaluated to ensure it adequately addresses the requirements, employs appropriate fidelity, and contains only elements that establish the simulation environment and address the operational and mission objectives defined for the intended use (i.e., does not involve elements beyond the scope of the intended use.

> Example:
>
> A scenario set in Panama should be eliminated when the purpose of the application is to evaluate the detectability of desert camouflage equipment.

Document Requirements Verification Activities

The V&V Agent should document and report results as appropriate for the intended use. Documentation should normally include the objectives, assumptions, constraints, methods used, data, and results (including problems and limitations) and recommendations. The V&V Agent should meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort.

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Results and recommendations should be addressed to the User and/or Accreditation Agent, depending on the reporting and approval structure established and documented in the V&V plan. Additional information is available in the section on Documentation Requirements [p. 53].

Characterize Simulation Capabilities

The V&V Agent uses the legacy simulation information obtained during *Collect Simulation Information* [p. 9] to catalog or characterize the simulation capabilities in terms that can be compared to the capabilities needed for the intended use. The V&V Agent works with the User, Developer, and SMEs to extract the detailed information that needed to define the simulation's capabilities and limitations . The V&V Agent should ensure that an appropriate format is used to facilitate comparison.[17]

Although the M&S requirements define what is needed for the intended use, they may not be expressed in terms that specify detailed simulation capabilities. The V&V Agent should work with the User, Developer, and SMEs to articulate the simulation capabilities needed for the intended application. These should be organized using the same format as the legacy simulation capability characterization.

Identify Simulation Inadequacies

Once the simulation's capabilities have been characterized and the M&S requirements have been expressed in simulation-capability terms, they are compared to determine if any deficiencies exist in the simulation and what should be done to address them. The results of this analysis are used by the User to answer the questions:

Can the simulation be used?

Can the simulation be used as-is or does it need to be modified?

In situations where the intended application is very similar to previous usage of the simulation, this may be done by straight comparison. In many situations, particularly when there is great difference between the intended use and previous legacy simulation applications, this decision may need additional information resulting from a preliminary validation of the existing simulation. The V&V Agent compares the simulation capabilities to the referent to compute the accuracy of the simulation's representations then compares the computed accuracy with the acceptability criteria. When the simulation capabilities, referent and acceptability criteria contain adequate detail and are described in comparable terms, then these comparisons can be relatively simple. However, if the acceptability criteria or referent are described in highly abstract terms then SMEs may be needed to make these comparisons and judge the suitability of the unmodified simulation for the intended use.

[17] See the RPG template on Common VV&A Formats for additional information.

This early validation activity identifies which M&S requirements are adequately captured by the existing simulation and which are not. Those that are not adequately captured fall into three categories:

- **unmet requirements** -- requirements that are not represented in the existing simulation
- **inadequately met requirements** – requirements that are represented but not with the needed fidelity
- **incompatible requirements** – requirements that conflict with existing simulation representation

These unmet, inadequately met, and incompatible requirements translate into simulation deficiencies that will need to be addressed if the simulation is to be fit for the intended purpose. Once these deficiencies are identified, the User and Accreditation Agent should review them to determine which are critical for the success of the application and by what means they will be addressed. Although some deficiencies may be resolved by refining the requirements, changing the data, or involving a different simulation, the critical deficiencies become the focus of simulation modification since they must be corrected to ensure the simulation can satisfy the intended purpose.

Assessing the Simulation for the Intended Use

When the simulation is to be modified, the V&V Agent supports the modification effort with the activities described in the section on *Providing Support for the Modification Effort* [p. 34]. However, several V&V activities should be performed to regardless of whether the simulation is to be modified. The input data need to be verified and validate for the intended use and the results from executing the overall implementation need to be compared against the representational requirements of the intended application. Further, depending on the completeness and credibility of existing simulation information, additional verification tasks may need to be performed.

> Examples:
>
> The intended application requires the simulation to represent medical evacuation. Although the simulation was developed with this capability, it was not needed in previous uses and this capability was never verified or validated.
>
> The intended application involves a new scenario operating with different force structures under different environmental conditions. New data are needed to support this scenario and some will be obtained from new sources. The data and algorithms employing them will need to be verified and validated to ensure a proper fit.

The following sections describe each of the V&V functions associated with preparing the legacy simulation for the intended use and present some suggestions for tailoring their scope.

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Develop the V&V Plan

The V&V plan consists of an agreement of what V&V tasks should be done, when they should be done, what V&V products should be produced, what resources are needed, and what relationships exist between the V&V effort, simulation preparation, and the accreditation assessment. A V&V plan is needed regardless of whether the legacy simulation is to be modified. Planning should be initiated as soon as the accreditation information needs[18] have been determined. If the V&V Agent has not been designated, the initial V&V plan may be developed by the User or Accreditation Agent.

This plan will need to be revised once the decision is made about modification. The V&V plan should be developed in coordination with the accreditation plan and the simulation plan (preparation or modification) and approved by the User. The quality and comprehensiveness of the plan greatly affects the effectiveness of the V&V effort in supporting the accreditation assessment.

V&V planning involves the factors and tasks listed below and discussed in the following paragraphs:

V&V Planning Factors

A number of factors must be considered before the final plan and cost estimate can be generated because each impacts the selection, level of effort, and scope of the V&V tasks involved. These include:

- **Accreditation Information Needs** -- The V&V Agent needs to have a good understanding of the accreditation information needs [p. 44] (e.g., M&S

[18] Information identified by the Accreditation Agent that is needed to assess the simulation's fitness for purpose.

requirements, associated acceptability criteria, accreditation priorities). The V&V Agent should work with the Accreditation Agent to determine what support is needed from the V&V effort. The completeness and consistency of the M&S requirements for the intended application can greatly affect the amount of effort required for the V&V activities. Spending the time at the beginning to understand the M&S requirements and the accreditation information needs can significantly reduce the V&V effort by focusing on appropriate tasks. It also improves the reliability of the V&V products by reducing the opportunities to introduce errors.

Accreditation information needs are used to identify what information will need to be produced by the V&V effort. Questions the V&V effort will need to address are shown in the following table.

Questions to Ask about the Accreditation Information Needs
• How do simulation assumptions, limitations, errors and approximations affect the intended application?
• Are the assumptions, limitations, errors, and approximations reasonable for the intended application?
• What are the key simulation sensitivities, and are they reasonable for the intended application?
• Are instance data well defined and consistently used?
• Do instance data agree with best estimates or intelligence information?
• What is the impact of identified data limitations on simulation use in the intended application?
• Does the software correctly implement the design?
• How well do simulation outputs compare with the referent?
• Does the simulation yield correct results for the set of problems associated with the intended application?
• What is the impact on simulation use in the intended application of each problem, limitation, and error discovered?

- **Information Availability** -- V&V planning depends heavily on the information available and on the contributions of the other participants (e.g., User, Accreditation Agent, M&S Proponent, Developer). Information about the intended use obtained during *Verify M&S Requirements* [p. 13] and the simulation documentation obtained during *Collect Simulation Information* [p. 10] should be used to gain a sufficient understanding of the simulation and intended use.

Field Code Changed

Field Code Changed

- **Key Measures and Assessment Strategy** -- The V&V Agent should support the User, and the Accreditation Agent in identifying appropriate acceptability criteria. Acceptability criteria need to be defined for the requirements in terms of the measures involved (e.g., MOPs, MOEs).[19] These measures are typically based on actual situations and real systems that are being represented in the

[19] See the special topic on Measures for additional information.

simulation.[20] Although some of the acceptability criteria may be the same as the associated measures, many of the measures established for the overall simulation are too broad to be considered acceptability criteria.

- **Simulation Characteristics** -- The characteristics [p. 17] of the legacy simulation affect the V&V effort in several important ways. If the simulation's representational capabilities (i.e., its fidelity) differ significantly from those required for intended application, then substantial modification may be necessary and those modifications will involve considerable V&V Agent attention to ensure their validity. If a simulation is large and complex or built upon an obtuse simulation infrastructure, an intensive V&V effort may be needed to adequately understand the simulation's capabilities and limitations and infer the impact of any modifications upon its overall performance. The stability and maturity of the simulation software and hardware can also affect the level of V&V effort needed. A stable and mature product may have undergone significantly more testing and may have fewer sources of errors than a less mature simulation system.
- **Resources and Schedules** -- Resource availability [p. 46] and schedule constraints can dramatically affect the quality of the V&V effort. The initial V&V plan should be tailored to address the accreditation information needs based on available resources and risks involved. However, the random nature of unexpected occurrences (e.g., nonavailability of data or hardware; evolving requirements) makes it difficult to adhere totally to pre-planned activities. Thus, resource allocations and schedules should both be flexible enough to allow priorities to be adjusted throughout the V&V process at the direction of the Accreditation Agent. V&V tasks should be scheduled in coordination with testing activities (e.g., development testing [DT], operational testing [OT])[21] and any corresponding modification activities involved (e.g., validation of the modified conceptual model should follow directly after the conceptual model is modified).

  The V&V activities should be coordinated with each phase of the legacy simulation's evolution and the modified simulation artifacts should be evaluated for correctness. A formal reporting and decision structure should be established based on the needs of the project.

[20] When possible, validation compares simulated performance and effectiveness to real measured performance and effectiveness. How well they match when the simulation is exercised is a strong indication of its validity and fitness for the intended use. When future systems are involved, the measures are normally based on system requirements, if they exist, and SME opinion.

[21] See the reference document on T&E and V&V Integration for additional information.

Example:

If there is no simulation modification involved and operational risks are low, then the V&V Agent may receive instruction directly from and report directly to the Accreditation Agent.

If extensive modification is involved or the risks are high, then the V&V Agent would report to and receive instruction from the M&S PM.

- **Referent** -- Validation normally involves comparing the simulation's representational capabilities and the referent to measure the simulation's accuracy.[22] Data describing the referent need to be identified and collected or developed. Real-world empirical data may be preferable (e.g., physical measurements, historical records). Data can also be collected from testing (e.g., live tests, developmental tests, operational tests), or from validated simulation results. In some instances, validation data from previous use of the simulation may be appropriate for the intended application. When real-world data are not available, validation data can be developed using SMEs. Appropriate test scenarios or use cases (to be executed by the simulation later) should be devised and SMEs asked to provide reasonable, expected outcomes [Rothenberg et al., 1997]. These validation data, both empirical and expected outcome, should be carefully evaluated to ensure they are appropriate to use.
- **Tools and Equipment** -- Sharing tools and equipment [p. 45] (e.g., data and databases, archives and libraries, test beds, communications, and support software) is highly recommended because of the normally compressed timelines and scarcity of resources. It also significantly reduces the possibility of problems caused by using different tools and equipment to modify and test the simulation.
- **V&V Participants** --The V&V participants [p. 46] should have extensive experience in the V&V field, the systems and technologies represented in the simulation, and the domains encompassed in the application. Selection of additional participants (e.g., SMEs) should be based on specific knowledge or experience they possess, their understanding of the software and hardware being used, and the scheduling of activities and events.[23]
- **Risk** -- Risks associated with the use of a legacy simulation are centered on how well the simulation will meet the needs of the intended application and whether the V&V effort can be accomplished in the time available and for the assigned budget. When modifications are to be made, additional risk associated with the changes is also present. All legacy simulations have inherent risk that arises from uncertainty about their actual capabilities and the correctness of those capabilities. This risk exists even if all the software can be examined; however, it increases when simulation documentation is incomplete or resource limitations prohibit a thorough investigation. The V&V Agent should provide estimates of the cost associated with additional effort directed at reducing risk.

[22] See the special topic on Validation for additional information.
[23] See the special topic on Subject Matter Experts and VV&A for additional information.

- **Tailoring** -- Tailoring [p. 26] is the process of selecting and balancing the level of the V&V effort against the risks and priorities of the application to provide sufficient evidence for the accreditation assessment. A tailored approach is reasonable and balanced (neither excessive nor insufficient), consisting of V&V activities that are coordinated with the simulation preparation process and tasks that match the accreditation priorities, with adequate funding and resources to complete the tasks and provide adequate evidence for the accreditation assessment. Tailoring is closely linked to leveraging because tasks that can be leveraged to free up funding and resources for use on other tasks.
- **Leveraging** -- Leveraging [p. 48] is the technique of using the results of work performed by others to support the V&V needs. In addition to leveraging data, scenarios, use cases, and results from testers associated with the simulation preparation effort (e.g., developmental testers, operational testers), the legacy simulation documentation may contain information about previous tests and V&V activities that can be used. The V&V Agent still has an obligation to review leveraged products and results to ensure they are acceptable. Such reviews typically require much less time- and can be less labor-intensive than if the tasks were repeated independently. Leveraging opportunities are the greatest when the intended use is similar to previous uses and when legacy simulation's capabilities closely match the M&S requirements of the intended use (thus affecting the amount of modification required).
- **Data --** Data V&V [p. 28] is an integral part of the simulation V&V process. The level of effort involved in data V&V activities varies from very low--for data types used in the simulation before, to moderate--for new data prepared by authoritative sources and accompanied by extensive information regarding data quality, to high--for data that must be generated "on the spot" from available sources (e.g., live tests, experiments, SME opinions). In the latter case, additional data V&V work may be needed to ensure data quality.[24]

Assess V&V Risks

The V&V Agent also supports the User and Accreditation Agent in identifying simulation limitations and constraints that impact the intended use and mitigating risk. These risks are of three types:

- **Development risks** -- risks associated with modifying the legacy simulation due to compromises made because the simulation does not exactly meet the needs of the intended application (e.g., inadequate or inaccurate representations) or to potential problems in addressing the technical, scheduling, or resourcing aspects of the modification effort
- **Operational risks** -- risks arising from using the incorrect simulation results believed to be correct

[24] See the RPG template on Data Quality for additional information.

- **Inherited risks** – effects carried forward from the original development or previous usage, such as those resulting from
  - undocumented assumptions, limitations, and constraints
  - errors and defects that were either undetected or considered insignificant in previous applications

Development and inherited risks are the focus of verification activities that examine and assess the integrity, correctness, and completeness of the simulation and the modifications involved. Operational risk is the focus of validation activities that examine the correctness of the interactions, behaviors, performance, accuracy, and predictability of the simulation in the context of its intended use.

Additional risks are associated with the V&V program itself. These include

- lack of resources needed to perform the necessary V&V tasks
- inadequate time to complete the necessary V&V tasks
- delays in receiving information
- inability to obtain SMEs when needed
- problems with sharing common development and testing resources

Risks associated with the V&V program should be identified as early as possible. Risks associated with the simulation should be assessed jointly by the User and V&V Agent; operational risks should be assessed in concert with the Accreditation Agent and/or the User.

Construct the V&V Plan

The V&V plan documents all the V&V tasks and activities required to achieve the objectives (and contractual requirements) of the V&V project. V&V planning depends heavily on the information available as well as on the contributions of the other participants (e.g., User, Developer Accreditation Agent, M&S PM). The quality and comprehensiveness of the plan greatly affects the effectiveness of the V&V effort in supporting the accreditation assessment.

The following steps comprise the V&V planning function:

V&V Planning Steps
• Establish V&V objectives based on accreditation information needs.
• Determine what V&V tasks are required and the level of effort of each; when modifications are planned, identify the V&V tasks needed to address the modification phases and artifacts involved

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V&V Planning Steps
• State how each task will be accomplished and what M&S requirements and objectives each will address; include any plans to leverage off work performed by others
• Determine what techniques will be used and assign responsibilities for each task
• Designate areas of responsibility (e.g., scheduling, providing resources, performing the task, collecting and analyzing data) for each leveraged task
• Determine required completion dates based on overall program requirements
• Identify other required resources (e.g., tools, SMEs, additional support personnel, additional hardware or software, travel) and determine if planned resources are adequate
• Tailor [p. 26] the plan (i.e., modify or change tasks) as necessary to balance requirements, risks, resources, and schedule constraints
• Identify products to result from each V&V activity (e.g., the objectives, assumptions, constraints, methods employed, data, tools, techniques, artifacts produced, and results of each task performed) and establish formats for each that comply with existing simulation configuration management guidance.
• Establish points of contact (POCs) with all participants (e.g., M&S Proponent, User, Accreditation Agent, Developer, M&S PM, testing agents)
• Gain concurrence on the adequacy of the plan to support accreditation from the Accreditation Agent and the M&S User

The V&V plan should be handled as a living document: iteration is to be expected. The above steps should be repeated as required until the M&S requirements and modification plans are stable and until the Accreditation Agent (or User) and V&V Agent agree that the proposed plan can provide the necessary information for accreditation. When requirements are changed, added, or eliminated; when the schedule changes; or when the scope of the modification is redefined, the V&V plan should be adjusted as well.

Tailor the V&V Plan

Tailoring is the process of selecting appropriate V&V tasks and an appropriate level of effort for each based on the priorities and needs of the accreditation assessment. The risks identified and prioritized by the User and Accreditation Agent during the risk assessment show the problem areas of the simulation.[25] The accreditation information needs identify what information the Accreditation Agent needs to conduct the accreditation assessment.[26] The objective of the V&V effort is to gather the evidence to support the accreditation assessment and the accreditation decision. A well-tailored V&V effort will provide sufficient evidence for the accreditation to establish the fitness of the simulation for the intended purpose. See Appendix C for additional information.

[25] See the special topic on Risk Assessment and Its Impact on VV&A for additional information.
[26] See the core document on the Accreditation Agent Role in the VV&A of Legacy Simulations for additional information.

The V&V effort should be tailored to include just those tasks that will provide the evidence needed for the accreditation assessment. The basic factors impacting the size and complexity of the V&V effort include

- what information is known about the existing simulation
- what information is needed about the modification effort
- what information is needed for the accreditation assessment
- the size and magnitude of the modification involved

Simulation modifications are generally considered to fall into three categories:

- **Isolated changes** -- simple, straightforward, isolated changes in the software or hardware
- **Minor modifications** -- changes that are more complex than isolated changes but involve less than roughly 30% of the software or hardware
- **Major modifications** -- changes that involve more than roughly 30% of the software or hardware

While tailoring the V&V plan, the V&V Agent should look for opportunities to leverage off the work of others to save resources (e.g., software verification by the Developer, DT, OT). However, the act of leveraging incurs some risk so all leveraged tasks should be approved (by the Accreditation Agent or User).

Tailoring is often an iterative task. If the available resources (e.g., funding, time) are insufficient to accomplish all the V&V tasks considered necessary, the tasks should be focused on the highest priorities of the accreditation information needs and the most critical M&S components or functions as determined by sensitivity analyses. If the available resources are insufficient to accomplish even the most critical tasks, the Accreditation Agent and M&S User must be informed so decisions can be made to either accept lesser credibility (and hence increased risk) or adjust program funding and schedules to accomplish the necessary V&V tasks.

Document Planning Activities

The V&V plan represents an integral part of the V&V documentation package. As a result, the V&V Agent should take care to adequately document the plan, to include the information that contributed to it, the methods and techniques employed, and the risks and uncertainties associated with the effort. The V&V Agent should also work with the M&S Proponent to ensure documentation formats comply with configuration management practices. Additional information is available in the section on Documentation Requirements [p. 53].

Verify As Needed

The primary focus of the V&V effort is to collect evidence for use in the accreditation assessment. The extant of the effort, even when no modification is involved, will depend upon the availability and condition of the existing simulation artifacts and completeness of the information that is available. When artifacts are missing or when there is uncertainty about the completeness or relevance of the information, the Accreditation Agent may ask the V&V Agent to perform additional V&V tasks. Typical functions that may need to be performed are listed below and discussed in the section on Providing Support for the Modification Effort [p. 34].

- Trace M&S Requirements [p. 35]
- Validate Conceptual Model [p. 36]
- Verify Design [p. 40]
- Verify Implementation [p. 42]

Information on additional V&V tasks can be found in the core document on the *V&V Agent Role in the VV&A of New Simulations*.

Verify and Validate Data

A legacy simulation was originally designed to use particular categories of input data prepared in specific ways all based on the needs of the original application. The data elements and the forms they assumed were selected to fit the algorithms built into the software. Unless changes are being made to the algorithms involved, the intended application will need to use the same kinds of data, organized and prepared in the same way. However, even when the existing data categories and structures are sufficient for the intended use, different data values will be needed to

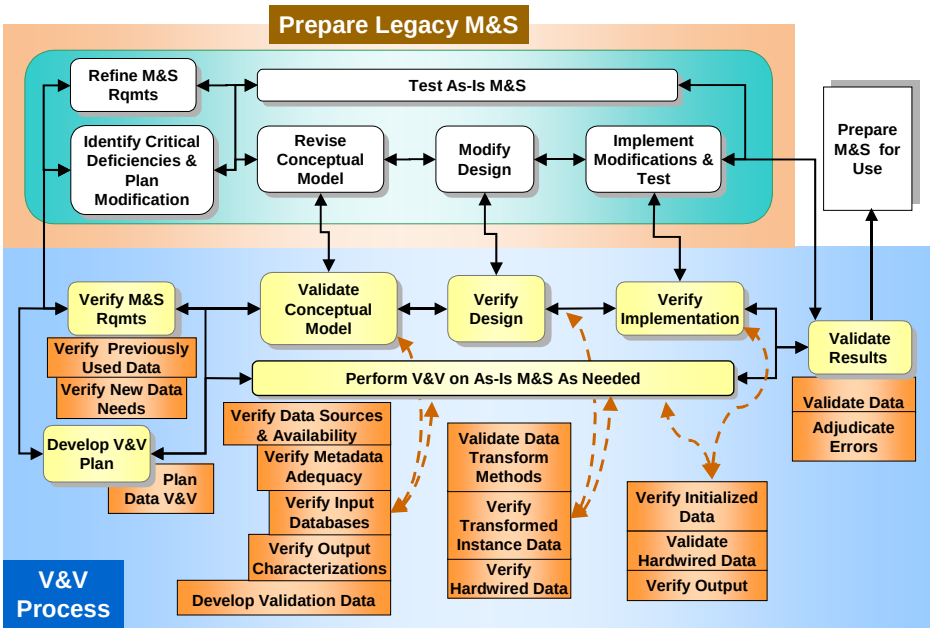
- represent new scenarios
- represent new objects or behaviors in the simulation
- correct or update existing data, objects or behaviors
- accommodate a change in the level of security for the intended use
- accommodate software or hardware modifications
- accommodate changes in the algorithms using the data

It is normally unwise to simply reuse data values for a new use without review. Data sources provide quality data sets based on their understanding of the particular application and they cannot guarantee data quality for different applications. A factor as simple as the time of year being played in the scenario can result in numerous differences in data values.

Any new data should easily fit into the data organization and structures previously used in order to work in the simulation. If not, the data need to be transformed from their previous structures into those the simulation employs.

In legacy simulation reuse, the V&V Agent needs to understand what data sets and databases were previously used and how they were prepared and applied in order to ensure the data selected are appropriate for the intended application and can be used in the simulation. Data should be obtained as early as possible to allow time for data preparation and data V&V activities . In a legacy situation, data V&V tasks should be performed on every new data set involved in the simulation and for any data sets inherited with the simulation that are questionable. Because the number of different data sets involved in any simulation is extensive, priorities should be established based on the accreditation information needs.

Typical data V&V tasks are illustrated in the following figure and described in the subsequent paragraphs. More detailed information is available in the special topic, *Data V&V for Legacy Simulations*.



Data V&V for Legacy M&S

- ***Evaluate Instance Data Needs*** -- The identified needs for new input data should be reviewed to ensure that they are appropriate for the intended use (e.g., a data requirement for arctic terrain or deep forest is not appropriate for a desert scenario). The information needed to accomplish this task is usually available in the conceptual model.

- ***Verify Data Sources and Data Availability*** -- The User of a legacy simulation normally inherits information about the data sources previously used. These should be reviewed to ensure they are authoritative for the intended use. When new and different data are needed, the sources selected by the User should be investigated to ensure that they are authoritative and can provide the necessary data.
- ***Verify Databases and Metadata*** -- New input databases and data sets should be reviewed to ensure they contain the specified data in forms that are usable by the simulation. The metadata associated with the input data should also be reviewed to ensure that they provide sufficient detail regarding the quality of the data for effective use.[27]
- ***Validate Data Transformation Methods*** – Data is often transformed (e.g., aggregation, unit conversion) so it can be properly employed. The V&V Agent should ensure that the integrity of the data is not compromised by any transformation used. In addition, data that have been transformed or otherwise prepared for use in the simulation (e.g., composite data such as unit structures and threat models) should be evaluated to ensure that the formats and translation conventions used are appropriate for the simulation. The responsibility for validating these tasks is typically shared by the data provider, who provided the data and the metadata, the M&S Proponent or Developer, who selected or developed the transformation algorithms, and the V&V Agent.
- ***Verify Initialized Data*** -- This task compares the initialized data values with the values in the input databases to ensure the proper data are being initialized and the proper transformations (if any) have taken place. It can usually be done in conjunction with *Verify Implementation* [p. 42] and testing because the information needed to accomplish this task is available at that time.
- ***Validate Input Data*** -- This task determines the impact of the input data upon the behavior of individual algorithms and components and on the integrated simulation. Because the data and the simulation implementation are inextricably intertwined (i.e., if input data is not valid, then the behavior of the implementation cannot be valid), their validation should be conducted concurrently during results validation [p. 30]. In some respects, this part of results validation can be viewed as the calibration of data and model.

  The methods used to test data validity vary greatly, depending in part on the type of data involved.

[27] See the RPG templates on Data Quality for additional information.

> Example:
>
> The data needed to execute a simulation vary from the large databases such as terrain, atmosphere, sea, weather effects, etc. to such things as RF and IR signatures, characteristics of an artillery shell in flight, or the speed or motion of an object.
>
> Validation of the former may require significant resources, while the latter may best be validated in the context of tests in which the data are being used.

Although all data involved in simulation are subject to validation, in legacy simulations much of the input data used is inherited (i.e., used in previous applications of the simulation) and should have extensive validation histories that can contribute evidence of their validity. Such input databases should be reviewed to ensure that they contain appropriate data and the associated metadata should be reviewed to ensure that they provide sufficient detail for effective use in the intended application. New input data and data that most directly impact high-risk simulation capabilities (e.g., modified sections of the software, new behaviors) should be evaluated first.

Data V&V can be conducted incrementally. Critical path analysis can be used to order tasks to ensure dependencies are being correctly managed.

> Example:
>
> The terrain database for a battle simulation can be validated before battle entities and objects are added.
>
> Sensitivity excursions can be run to test the boundary conditions of key data elements and to assess the tolerance of simulation execution and output to variations in data values.

Regardless of who conducts the various data V&V activities, all information should be collected and recorded and included in the V&V report. Information pertaining to individual data sets should be provided to the data providers. Data problems that have not been corrected should be documented separately for use in the accreditation process. Additional information is provided in the section on *Documentation Requirements* [p. 53]

Validate Simulation Results

Results validation determines the extent to which a simulation's results address the requirements of the intended use. Even when a simulation is to be used *as-is*, its fitness for the intended application should be assessed through results validation.

The specific tasks performed and the techniques selected for each depend upon the type of simulation involved, the intended use, and the comprehensiveness of the simulation's VV&A history. Results validation is performed through the comprehensive,

iterative testing and assessment of the M&S requirements, acceptability criteria, and simulation functionality to ensure that everything is working correctly. It can also include regression testing on the unchanged portions of the simulation. Some unique dimensions of results validation can and should be conducted in advance:

- terrain and other synthetic environment databases with entities and objects included in dynamic states should be validated before as well as during execution of the integrated test effort[28]
- composite input data (e.g., threat models, unit structures) should be checked out well before they are needed in the integrated test effort (see *Verify and Validate Data* [p. 27])
- special hardware, such as cockpit or control center mockups required to support the simulation, should be checked out and validated as far as possible before becoming integrated with the rest of the simulation (see *Verify Hardware Configuration and Implementation* [p. 43])
- communication networks or external networks can be tested and validated long before being used for the checkout of the simulation (see *Verify Hardware Configuration and Implementation* [p. 43])
- common hardware platforms used for testing and off-line validation activities of specific test articles should be set up and checked out well before needed (see *Analyze Tests* [p. 44]).

Results validation should be supported by appropriate analysis tools.[29] It is often beneficial for the V&V effort to have some testing capabilities and tools to support results validation. The Program Manager (or the User, if the Program Manager has not been chosen) should make the decisions about which tools and test facilities to obtain and which to share based on economics, program needs, risk, and the amount of validation testing that can be leveraged from other sources (e.g., DT, OT, simulation VV&A history). When simulation software can be run on available computers or workstations, some level of independent validation testing should be conducted. When test facilities and resources are limited, they should be shared.

The results validation effort should ensure that the requirements map into the tests and the tests can support the acceptability criteria for accreditation as well as help assess the capabilities of the simulation. During planning, the V&V Agent should have developed detailed plans on how to conduct the validation and collect the necessary test data. The strength of this validation approach and the quality of the test data are critical to the validation effort. The following examples illustrate the importance of a referent to results validation.

[28] See the special topic on Foundations for V&V of the Natural Environment in a Simulation for additional information.
[29] See reference document on V&V Tools for additional information.

Example:

Attempts to validate a simulation in the absence of good test data or measured phenomena are very uncertain, often impossible, and can lead to completely false assumptions.

Early simulations of high-energy lasers, considered valid at the time, relied on a number of assumptions about the physics involved. When hardware prototypes were built and tested in the atmosphere, these assumptions were found to be incorrect.

Conversely, the performance capabilities and behaviors of a fielded Army Helicopter are so well known that its referent could be assembled for a wide range of applications from real-world test data.

Tasks associated with results validation are listed below and discussed in the following sections.

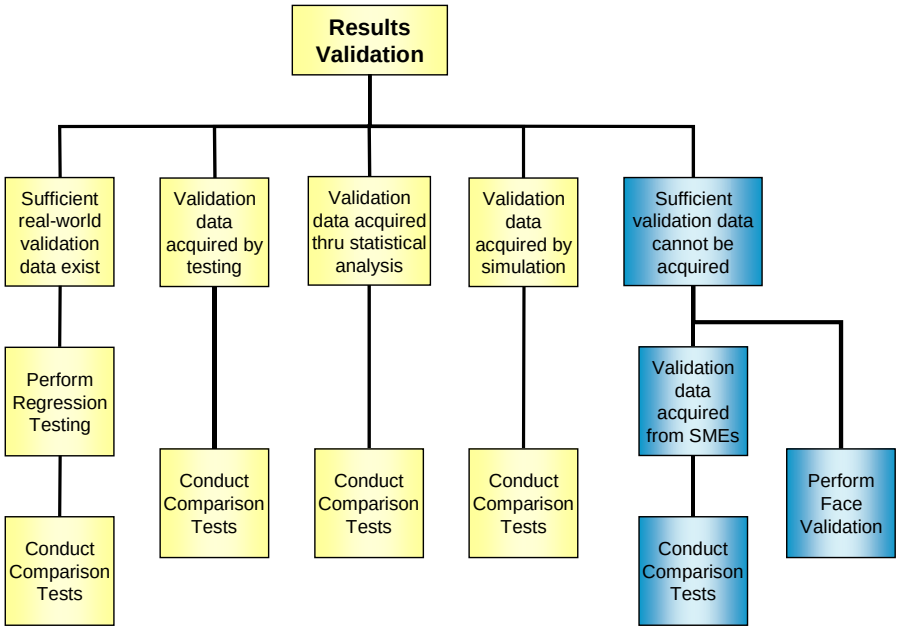
- Conduct Validation Testing [p. 32]
- Validate Required Representations [p. 33]
- Adjudicate Errors [p. 34]
- Document Results Validation Activities [p. 33]

Conduct Validation Testing

One of the key objectives in results validation is to ensure that testing has thoroughly addressed the acceptability criteria and provided acceptable output values. The following figure [p. 33] shows the five basic approaches to conducting results validation depending on the availability of validation data describing the referent [p. 22] (e.g., real-world data, results from operational tests and evaluations, results from other accredited simulations, statistical analysis or SME opinion) to support comparison with the simulation results. The choice of technique depends a great deal on how deterministic and predictable the simulation outputs happen to be. Whichever techniques are chosen to determine acceptability should be documented.

The first four alternatives are quantitative in nature. The preferred approach is always to have access to observe, "real-world" data. The second alternative is to locate test data from experiments, live tests, etc., or to use results from ongoing tests performed by the Developer or by the user community.[30] When such testing is not practical, data may be obtained through statistical analysis or from another (accredited) simulation (e.g., previous versions of the legacy simulation). These are likely to be less expensive and time-consuming than testing alone.

[30] Note that comprehensive DT and OT are expensive and time-consuming processes and are feasible only for major programs with lengthy schedules and significant resources.



Alternative Results Validation Approaches

The final alternative is using SMEs. SMEs may be involved in developing the validation data to be used in comparison testing or may perform face validation (i.e., observe simulation execution and review the results). In either case, relying on subjective opinions increases the importance of previously conducted V&V activities (e.g., conceptual model validation and design and implementation verification) and suggests that more resources should be expended to accomplish them when the results validation cannot be quantified. See the special topic on *V&V Techniques* for a catalog of analytic techniques that can be applied in validation and verification activities.

Validate Required Representations

This task examines the extent to which different aspects of the modified simulation can provide appropriate behaviors and responses when driven by valid instance data and exercised in the context of scenarios specific to the intended use. Attributes of the internal models and their representations should be examined independently and in the context of their interactions with other entities. As time and resources allow, this task should be extended to ensure the unchanged sections of the simulation are not adversely impacted by the changes.

Adjudicate Errors

Identifying the cause of an error is the first step in resolving the problem. Inconsistencies, errors, and discrepancies between simulation results and the referent should be examined to determine their probable causes. Emphasis focuses first on all modified portions and transitions to the unchanged portions. Obvious errors can result from many sources, such as problems in the hardware, software, data, or a combination of all three.

Anomalous outputs should be traced back through the software to determine where the problem initiated. This may involve tracking to the design, the conceptual model, or even to a requirement that cannot be met consistently. A large class of anomalous behavior and borderline performance should be evaluated using engineering judgment and/or further test runs to attempt to isolate the cause and determine if the problem is real or not. Sensitivity analysis, Monte Carlo runs, and other analysis techniques can sometimes support this activity, and previous users of the simulation can be contacted for consultation and advice.[31] It is very important that the results of all such investigations, testing, and assessments be documented and included in the results validation report.

Document Results Validation Activities

The V&V Agent should collect and record all information associated with each results validation task (regardless of who performs it), including objectives, assumptions, constraints, methodologies, data, and results (e.g., problems, limitations, recommendations). The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort. Any problems or limitations that are not corrected or addressed by the Developer should be documented separately for use in the accreditation process.

Document the V&V Effort

The final task of the V&V Agent is to produce the V&V Report. Throughout the V&V effort, the V&V Agent should have documented each activity as it occurred, sharing problems and issues with appropriate decision makers as an ongoing task to ensure they could be addressed quickly. Once results validation has been completed and the results have been accepted (by the Accreditation Agent or User), the V&V Agent prepares a formal V&V report that contains the documentation from all preceding activities. See Documentation Requirements [p. 53] for additional information.

Providing Support for the Modification Effort

In supporting the simulation modification effort, the V&V Agent verifies the simulation artifacts that are modified (e.g., the code, design documentation) and validates the modified simulation conceptual model. The particular sequence of these verification

[31] See the special topic on V&V Techniques for additional information.

functions depends upon the development paradigm that the Developer chooses to guide the modification effort.[32] They may be executed incrementally and iteratively as that modification proceeds.

The V&V Agent should participate in the rapid review and assessment of the modification artifacts throughout the modification process. This participation becomes an essential element in ensuring the quality and completeness of the various modification products (e.g., conceptual model, design, software) and the thoroughness of the testing. To make this interaction work effectively, the V&V Agent needs ready access to the data, documents, and interim products being created and changed. The Developer needs to understand that the V&V effort is being done to improve the quality of the products and to increase the likelihood that the simulation will satisfy the User's needs. The V&V Agent has a responsibility to review modification products and determine their adequacy for V&V and accreditation purposes, while leveraging as many of these products as possible.

Four V&V functions are normally done to support the modification effort.

- Trace M&S Requirements [p. 35]
- Validate Conceptual Model [p. 36]
- Verify Design [p. 40]
- Verify Implementation [p. 42]

Trace M&S Requirements

Requirements tracing, discussed in *Establish Requirements Tracing* [p. 14], provides much useful information and facilitates the implementation of other verification and validation tasks. The M&S requirements should be traced through each of the major simulation artifacts to ensure they are adequately and consistently addressed. This task should occur in concert with other V&V tasks associated with each simulation development artifact.

- When validating the modified conceptual model [p. 36], the V&V Agent should review the elements included (e.g., entities, characteristics, behaviors, relationships) and map them to the M&S requirements. M&S requirements that are not addressed or are inadequately addressed in the conceptual model should be reported to the Developer for correction.
- When verifying the designs [p. 40], the entities, characteristics, and relationships addressed in the modified designs should be mapped back to the validated modified conceptual model to ensure that the elements addressing the M&S requirements are appropriately captured in the modified design.

[32] See the special topic on Paradigms for M&S Development for additional information.

- When verifying the modified implementation [p. 42], the representations and behaviors defined by the M&S requirements and their associated measures, and acceptability criteria should be traced from the design to the code and hardware. Because a single requirement can expand into several design statements which, in turn, may need to be represented in multiple lines of source code, there may be only a loose correlation between requirements, design statements, and lines of code. This makes the job of tracing requirements through to the software and hardware a complicated task and a tracing tool or database is recommended.
- When verifying the test plans [p. 41], the test activities should be mapped to the M&S requirements to ensures that every testable M&S requirement is appropriately addressed in one or more tests and none is left untested. All tests conducted on the simulation (e.g., DT, OT, validation testing) should be mapped to the M&S requirements and their associated metrics and acceptability criteria. This should provide pass/fail values for all essential expected test outputs.

Validate Conceptual Model

A simulation conceptual model is *the Developer's description of what the model or simulation will represent, the assumptions limiting those representations, and other capabilities needed to satisfy User's requirements* [RPG Glossary].[33] It should include descriptions of entities, objects, algorithms, relationships (i.e., architecture), data, assumptions, limitations, and known errors. It should present a thorough functional-level description of the simulation's representational capabilities, describing what entities the simulation represents and how well it represents them. It should also

- connect the detailed design to the requirements through a comprehensive description of the representational capabilities addressed by the simulation's design
- support the transition from requirements to detailed design and implementation by serving as the framework where the M&S requirements are converted into the necessary capabilities needed by simulation
- describe the simulation's capabilities (e.g., missions, operations, behaviors) that agree with the mission and operational requirements defined by the scenario
- include descriptions that adequately characterize the real-world systems, entities, interactions, and environments specified in the intended use.

The conceptual model also bounds the referent for the simulation by delimiting the characteristics of an adequate representation of the performances, behaviors, interactions, and fidelity needed to meet the intended use.

The Developer responsible for doing the modification should begin by creating a conceptual model for the modified simulation based on the existing conceptual model

[33] See the special topic on Conceptual Model Development and Validation for additional information.

for the legacy simulation. If none exists in an accessible form, a new conceptual model should be created based on existing simulation documentation and the M&S requirements of the intended use. Validating the conceptual model can identify miscommunications and Developer misconceptions about the intended use before they impact the design or implementation of the modification.

Even when a legacy simulation requires no modification, the V&V Agent may wish to review the existing simulation conceptual model to determine that previous conceptual model validation was sufficient to meet the needs of the intended use. If the former effort is insufficient, then the V&V Agent may wish to perform supplementary conceptual model validation to reduce the burden on the results validation effort.

Tasks associated with conceptual model validation are listed below and discussed in the following sections.

- Assess Adequacy of Conceptual Model [p. 37]
- Compare Conceptual Capabilities and Representational Requirements [p. 38]
- Document Conceptual Model Validation Activities [p. 39]

Assess Adequacy of Conceptual Model

The V&V Agent should check the modified conceptual model to ensure that it contains enough information at a sufficient level of detail to determine the modified simulation's ability to meet the needs of the intended use as articulated by the acceptability criteria. In some reuse situations, a formal conceptual model may not exist or may be incomplete (e.g., the simulation being used is itself a modified version of the original simulation and the conceptual model has not been revised to address those modifications). In such cases, the information normally found in the conceptual model should be located elsewhere.

> Example:
>
> In object-oriented simulations, use cases can be used as the mechanism to move from requirements to design, bypassing a more formal conceptual model [Jacobson, 1992].

If no formal conceptual model exists, the V&V Agent or Developer may be tasked to assemble all available information artifacts and products (e.g., descriptive information, diagrams, algorithms, behaviors, performance data, scenarios, constraints, representations, limitations, interactions, operational and mission descriptions) into a surrogate conceptual model. Additional time and resources would be needed to plan, assemble, and validate this conceptual model and additional assistance would be needed to identify, collect, and apply the various pieces of information involved.

When the conceptual model is inadequate or incomplete, the User can either direct the Developer or V&V Agent to correct the deficiencies or may decide to accept the conceptual model without enhancement. However, the decision to accept an inadequate conceptual model pushes the burden of building credibility onto results validation. This can be an expensive choice since invalid behaviors that would have been identified during conceptual model validation may not be caught until the results are validated and tested, resulting in delays, additional costs and possibly additional errors.

Compare Conceptual Capabilities and Representational Requirements

The meat of conceptual model validation consists of validating the simulation capabilities defined in the conceptual model against the M&S requirements they are intended to represent. This can be done using one or two methods. The first involves two distinct steps.

- The *simulation elements*[34] of the conceptual model are compared with the referent to calculate its *accuracy*[35] or conformance with known reality.[36]
- The conceptual model, together with its computed accuracy, is compared with the acceptability criteria to determine if and where the simulation's design (as represented in the conceptual model) meets the acceptability criteria. The manner of executing these two steps depends upon the levels of detail of the conceptual model and the acceptability criteria and the form of the referent.

The representational requirements for a simulation, as depicted by the acceptability criteria, should specify

- what the simulation must represent (i.e., level of detail or resolution)
- how well those representations should conform to what is being represented (i.e., accuracy)
- the bounds within which the simulation should produce the required accuracy (i.e., domains of applicability)
- the confidence that the User needs to have in the simulation's ability to address the intended use

Whenever the acceptability criteria stipulate required accuracies (or acceptable error limits), the representational requirements should also specify the referent (or at least where and how to get referent information that is credible to the User). The referent

[34] The entities/processes (tasks, actions, behaviors, etc.) represented by assumptions, algorithms, data, and relationships (architecture) included in the simulation concept portion of the conceptual model [Conceptual Model special topic].
[35] In simulation, ***accuracy*** is the *fidelity of the representations; quality and precision of the input data; how closely the results correspond to the intended view of reality* [RPG Glossary].
[36] See the special topic on Conceptual Model Development and Validation for additional information.

describes the behaviors and characteristics of the subject being represented against which to measure simulation accuracy. Ideally, the acceptability criteria, referent, and conceptual model will be described in easily comparable terms.

Fidelity provides the construct by which the capabilities of the simulation can be characterized.[37] The notion of simulation fidelity rigorously defines the terms through which to consistently describe both representational requirements and simulation capabilities in comparable form.[38] Thus, using the fidelity terms simplifies conceptual model validation to a straightforward comparison of the differences between the simulation capabilities (as described by the conceptual model) and the acceptability criteria.

The advantage of this approach is that it is objective. However, if either the simulation conceptual model or the M&S requirements does not take this consistent and well-defined form then a simple and objective comparison of capabilities against requirements is not available and the second method, that of relying on SME assessment, should be used.

In the second method, SMEs play the roles of referent, interpreters of the requirements, and judges of conformance to the requirements. In most cases, this method consists of a series of qualitative reviews and assessments by the V&V Agent and appropriate SMEs to determine if the various parts of the conceptual model are adequately defined and represented. The modified conceptual model is reviewed to ensure

- an accurate, clear, and complete description exists of all the modified simulation capabilities
- the modified capabilities address the needs of the intended application
- representational requirements of the intended application are adequately met

When M&S requirements are added or changed and verified, they need to be incorporated in the conceptual model and that incorporation validated. When the conceptual model validation effort identifies gaps or inconsistencies in the M&S requirements, these should be reported to the User for resolution.

Document Conceptual Model Validation Activities

The results of the conceptual model validation activities should be documented and reviewed as specified in the V&V plan. This report should contain a description of the tasks completed and should indicate how thoroughly and accurately the conceptual model represents the M&S requirements, what portions of the legacy conceptual model were investigated, and how extensive the investigation was. It should also contain an

[37] See the special topic on Fidelity for additional information.
[38] In the special topic on *Fidelity,* fidelity is described as a framework based on the relationship between the following terms: *accuracy, capacity, error, fitness, precision, resolution, sensitivity, tolerance,* and *validity*.

assessment of the adequacy of conceptual model for the intended use and it should identify its deficiencies.

Verify Design

Design verification can help ensure that the M&S requirements are correctly and completely included in the design and design documentation and the modification has not compromised the rest of the design. Design verification tasks rely heavily on development documentation such as algorithms, design peer reviews, diagrams and drawings, interface control drawings, database formats, and the designs themselves.

The V&V Agent should ensure that all M&S requirements are correctly traced [p. 35] and that data[39] to be used in the simulation is available well before it is needed so that it can be verified and validated. The modified design is verified against the validated conceptual model to ensure all the features, functions, behaviors, algorithms, and interactions are adequately addressed. Even when a legacy simulation requires no modification, the V&V Agent may wish to review the existing design documentation to determine that the design verification done previously was sufficient to meet the needs of the intended application. If the former V&V effort is insufficient, the V&V Agent may wish to perform supplementary design verification to reduce the burden on the results validation effort.

Tasks associated with design verification are listed below and discussed in the following sections.

- Assess Algorithms [p. 40]
- Verify Design Artifacts [p. 41]
- Verify Test Plans [p. 41]
- Document Design Verification Activities [p. 42]

Assess Algorithms

Key algorithms should be examined for their fitness for the intended use (e.g., perform at an appropriate fidelity; provide useful, correct output) and the input data used in their execution should be examined for their accuracy and appropriateness. Although the primary focus should be on

- new algorithms,
- algorithms being changed by the modification effort
- algorithms that will be using new data

[39] See the reference document on Data V&V Concepts and Terms for additional information.

this effort should also examine algorithms already coded in the legacy simulation that have insufficient V&V histories or are critical to the intended use. This task can be leveraged with the effort to *Verify and Validate Data* [p. 27].

Verify Design Artifacts

The V&V Agent should review and evaluate the design artifacts from the original development, subsequent modifications, and the current effort for completeness and consistency. Gaps and inconsistencies, particularly those impacting the current effort, should be reported to the Accreditation Agent or User in a timely manner.

A number of different V&V tasks rely heavily on the artifacts and products resulting from the design process, such as design documentation, representations that correspond to the type of development involved (e.g., object-oriented, structured, knowledge based), algorithms, design and peer reviews, diagrams, drawings, interface controls drawings, and database formats. If the modification is extensive, the V&V Agent may need access to or copies of the software design tools used to support this task.

Verify Test Plans

Thorough testing of the modified legacy simulation is critical because modifications may produce unpredictable effects on simulation execution which, in turn, can produce unanticipated changes in simulation representational functionality and performance. The manner in which testing is to be performed varies greatly with the type of simulation, its intended use, and the availability of facilities and resources. Legacy simulation documentation should include sets of test plans, procedures, scripts, cases, data, and expected results. These can often be used as the basis for determining if the existing software is acceptable. They can also support regression testing of the unchanged parts of the simulation when modifications are made and results validated.

The V&V Agent should review and assess test plans to ensure they address the M&S requirements (e.g., requirements tracing [p. 35]) specified for adequate validation of the simulation) in terms of their associated measures and acceptability criteria. When possible, testing activities should be shared (e.g., scenarios, test cases, data, events, results) to minimize costs and increase efficiency.[40] The V&V Agent should work with the Developer and other testers to include validation test issues where possible. Separate, independent validation tests can be run, if necessary, although this is usually more costly in terms of time and resources. Balancing developmental and V&V test needs and objectives is an issue that should be resolved by the V&V Agent, Developer, and M&S PM during planning. Final agreements on test plans, activities, and areas of responsibility should be specified in both the V&V and simulation modification plans.

Document Design Verification Activities

[40] See the reference document on T&E and V&V Integration for additional information.

The results of the design verification activities should be documented and reviewed as specified in the V&V plan. This report should contain a description of the tasks completed and a recommendation on the adequacy of the design to meet the User's needs. In addition, any areas of the simulation considered high risk that were not examined should be identified. Artifacts developed during the original development effort and during the current modification effort may be included as attachments.

Verify Implementation

Implementation verification determines that the software and hardware implementation match the design, that all of the M&S requirements have been correctly traced [p. 35] to the software, and that the software performs correctly. Information from the unmodified simulation design, the validated conceptual model, and verified design changes are used to ensure that the design is faithfully represented in the implementation. If the legacy simulation has an adequate VV&A history, much of this effort should have already been done. However, the existing documentation should be reviewed and still may require updating to make it reflect the current software product. Using the hardware and tools applied in the original development and previous implementations of the simulation can have some advantages if they are not obsolete.

When the simulation is being modified, the V&V Agent should take every opportunity to participate in peer reviews, software walk-throughs, intermediate level testing, and integration testing and, in general, leverage as much of the Developer's work as possible. For example, if the Developer runs the software through a software analysis tool, the results should be used to address software verification.

Tasks associated with implementation verification are listed below and discussed in the following sections.

- Verify Software [p. 42]
- Verify Hardware Configuration and Implementation [p. 43]
- Analyze Tests [p. 44]
- Document Implementation Verification Activities [p. 44]

Verify Software

Software analysis tools can be a very cost-effective method for identifying latent defects that can then be corrected by the Developer.[41] Software can be run on static and dynamic analyzers to identify language standards violations, syntax errors, and poor coding practices; uncover latent logic errors; and help ensure accurate execution. Higher-end software analysis tools provide both static and dynamic software analysis. Static analysis focuses mostly on standards enforcement, flawed logic, coding errors,

[41] Code analyzers are much more effective and much less expensive than manual code reading and analysis, the primary alternative.

and violations of good software development practices. Dynamic analysis executes software on a tool-bearing host and can be used to focus selectively or can execute up to 100% of all paths in the software. The decision to use software analyzers is based on

- size of the modification
- complexity of the simulation
- risk associated with its use
- number of problems discovered in unit and intermediate level testing

According to years of studies done by tool pioneer Ed Miller, conscientious use of these tools should result in detecting 75 to 95% of the common software development errors [Miller, 80].[42] Regardless of who runs these tests (e.g., DT, OT, Developer, T&E Agent, or V&V Agent), the results should be included in the verification report.

Verify Hardware Configuration and Implementation

Interfaces between components should be checked to ensure they are implemented and that they work correctly even though they may not have been modified. When hardware integral to the simulation has been modified to address the intended use, the V&V Agent should verify that functionality of the modified hardware performs as required. One way this can be done is by participating in the testing. In some simulators (e.g., pilot training flight simulators), the likeness and simulated performance must be close enough to the real system that the user can scarcely tell the difference. In other cases, the simulation or simulator has to create an artificial or synthetic environment that mimics real terrain, behaviors, and performance of the real entities and objects. The challenge to the V&V effort is to select SMEs who have experience in the actual systems and who know how to assess the hardware for adequacy.

- ***Verify Hardware*** -- Diagrams and equipment used in the simulation may need to be compared to the actual systems being represented to ensure the representations are adequate for the intended use. When the modification effort involves changes in special hardware (e.g., systems that include physical models, cockpit mockups, visualization systems employing optics, simulators providing motion, custom built hardware), the verification effort can be extensive, involving the evaluation of the fabrication of the hardware and its integration into the existing system. In addition, hardware changes often involve corresponding software changes which will involve additional testing.
- ***Verify Hardware/Software Mapping*** **--** Software allocation to hardware components should be checked for correctness in accordance with revised specifications, good engineering practices, drawings, etc.

[42] See the reference document on V&V Tools for additional information.

Analyze Tests

The V&V Agent supports the Developer and other testers in the execution of the verified test plan [p. 41]. In the preparation of the test environment, the V&V Agent verifies test data and helps check the test equipment, hardware, and software to ensure they are working, calibrated correctly, and appropriate for the tests. During combined testing, the V&V Agent should help conduct and analyze test results, especially those that address V&V issues and acceptability criteria. When additional testing is needed to address V&V issues, the V&V Agent, supported by SMEs, establishes the test environment, conducts the tests, and analyzes the results.

Document Implementation Verification Activities

Implementation verification tasks should be documented as specified in the V&V plan. Results from activities such as software analysis should be presented to the Developer immediately for rapid attention. The V&V Agent should also meet with the Accreditation Agent to ensure that the information collected and reported meets the needs of the accreditation effort. Any problems or limitations that are not corrected by the Developer should be documented separately and archived for use in the accreditation assessment process.

VV&A Challenges of the V&V Agent Role

Some of the major challenges associated with a V&V effort of a legacy simulation are listed below and discussed in the following paragraphs.

Obtaining Well-Defined Accreditation Information Needs

At the beginning of the V&V effort, the Accreditation Agent should brief the V&V Agent on the ***accreditation information needs***, including the M&S requirements, their associated acceptability criteria, and the risks and priorities of each. The accreditation

information needs are used to bound the V&V effort. They should provide a complete detailed picture of the issues to be addressed. The V&V Agent uses them when determining what evidence to collect, what tasks to perform and how much time and effort to devote to each. The Accreditation Agent and V&V Agent need to establish a good working relationship from the beginning. When the simulation is being modified, the M&S PM should coordinate the assignments, needs, and responsibilities of both Accreditation and V&V Agents to avoid any misunderstandings in terms of the type and scope of the criteria, metrics to use, or what information and artifacts are needed to support the accreditation (See the core document on the *Accreditation Agent Role in the VV&A of Legacy Simulations* for additional information).

Dealing with Missing Documentation

One of the most difficult problems in legacy simulation reuse is locating documentation about the version of the simulation being used as well as evidence of its performance in earlier applications. Simulation development documentation is normally kept under configuration control by the M&S Proponent, but documentation describing simulation use in different applications may be available only from the individual Users. The VV&A history, in particular, may exist only as individual reports for different applications. Even when the M&S Proponent maintains the original development documentation, there may be no record of changes that have occurred over time, particularly if formal configuration control has not been maintained or individual Users have been allowed to develop their own versions.

In addition, because legacy simulations may have been developed under different policies, they may lack some of the expected development artifacts (e.g., conceptual model). Inadequate VV&A history and out-of-date simulation documentation increase the difficulty of determining the critical issues and operational risks associated with reusing the simulation, create uncertainties about simulation performance and the amount of modification needed, and cause delays in planning and implementing the modification effort.

One of the early roles of the V&V Agent may be to assist in the collection and review of available documentation and records and, when necessary, to generate information to fill in the gaps (*Collect Simulation Information* [p. 9]). The V&V Agent may have to interview previous users, piece together change histories and records, assess and correct key documents, perform tests, and generally build the set of evidence needed to obtain the information needed. In the recent past, repositories such as the DoD Modeling and Simulation Resource Repository (MSRR) have been established to archive some of this kind of material, but missing, incomplete, and poorly-maintained documentation remains a serious problem with many legacy products.

Field Code Changed

Establishing V&V Support Systems and Infrastructure

V&V efforts should establish a system of support mechanisms in order to function efficiently. This system should be scaled to the size and duration of the effort in order to

perform most cost-effectively. It is considered good practice to provide the minimum level of support and infrastructure that can function satisfactorily. When a legacy simulation is involved, the documentation available should provide some guidance regarding what support systems and infrastructure have proved effective in the past.

Some essential support components include:

- **Support Tools –** These consist of tool-bearing host computers and special software packages and tools, some of which are used by the original and/or current Developer.

  The V&V Agent has to begin with a good understanding of the magnitude and type of modification and assessment activities being considered before specific V&V tasks are identified and specific techniques selected. The V&V Agent should then look for tools that can be used in addressing the tasks involved (e.g., requirements tracing, code analyzers, database tools, regression analyzers).[43] Because a legacy simulation program seldom operates with a large budget, the V&V Agent should first see if tools used in the execution of the simulation or tools being used in the modification of the code are appropriate and available for use. Most of the time, these products can be obtained from the Developer (original or current) or the M&S Proponent. A more costly alternative is to make arrangements with individual tool vendors.

- **Documentation Library –** Although legacy simulations may be expected to have a documentation library, established and maintained as part of simulation configuration management by the M&S Proponent, in some instances the V&V Agent may have to assemble one. This library should contain

  - copies of all plans, reports, data, deliverables, and working papers pertinent to the simulation
  - reference books, papers, and materials and source documents pertaining to the systems being modeled
  - other inputs used in planning the intended use

  Libraries of this type are typically a combination of hard-copy documents and electronically stored media.

- **Software Library –** A legacy simulation software library contains all of the official releases of the software and the data and databases used for input (established and maintained as part of simulation configuration management by the M&S Proponent). It should also contain the test data from every test that the V&V Agent decides to assess, whether conducted by the Developer or the V&V Agent, regardless of purpose. The purpose for maintaining this information is to be able to recall and, when necessary, recreate tests at will and to quickly associate their software release, data, test cases, and procedures. It is most cost effective when a software library exists (as part of the simulation configuration management system) and the V&V Agent is allowed access to it.

[43] See the reference document on V&V Tools for additional information.

However, if the V&V Agent has to establish a separate library, either the same or a compatible code management system should be used.

- **Security --** Security involves both the physical security provided by the facility and the safe handling and storage of classified material, which is done in accordance with the DD Form 254 for the simulation project.

Finding Adequate Resources

Resource limitations can restrict the ability to gather all the needed information, decreasing the effectiveness of the V&V effort and increasing the risk [p. 24] that the simulation might not produce acceptable results for the intended purpose. Trade-offs between risk and resources should be identified and assessed by the V&V Agent and presented to the User for consideration and action. The Accreditation Agent and V&V Agent should work together to determine and prioritize specific V&V tasks based on resource estimates, criticality of the tasks in meeting the needs of the group, and risk. Program factors that have an influence on the V&V effort include:

- availability and quality of existing data and development artifacts
- stability of the M&S requirements
- level of detail and accuracy needed
- complexity and size of any modification
- perceived risks and uncertainties that can impact the V&V effort

The V&V resource estimate should include other direct costs (ODC) for such things as tools, hardware, support software, SMEs, etc. See the section on *cost implications and resourcing* for additional information [p. 54].

Selecting the Right People

A successful V&V effort requires skilled and experienced participants. Even though V&V techniques may be well defined at the technical level, the successful implementation of these techniques requires creativity and insight into the functional and representational requirements and acceptability criteria of the application. In addition, knowledge of the specific application, expertise in M&S methodology, and prior modeling and V&V experience are essential requirements to produce useful and applicable results.

The V&V Agent needs a thorough understanding of the intended use (i.e., objectives, M&S requirements) and knowledge of the legacy simulation, in order to identify the types of skills, experience, and educational background needed. Although some participants may be involved throughout the entire V&V effort, it is common to designate people with particular skills to perform specific tasks as needed.

> Example:
>
> When a legacy simulation is being modified, the Developer responsible for the modification should have the requisite skills and knowledge to successfully accomplish some of the planned V&V tasks (e.g., implementation verification). However, the Developer should not be asked to perform tasks that rely on subjective judgments (e.g., face validation) about the capabilities or limitations of the modified simulation without providing for independent review of the results.

A major challenge is identifying and locating SMEs to assist at critical points in the program.[44] Experts in the problem domain and user domain assist with requirements verification, conceptual model validation, and results validation; technical experts with specific knowledge of the programming languages, hardware, and software being used assist with design and code verification. Another challenge is choosing experts whom the User finds credible. The user community is usually the best source for experts in the problem and user domains, and the User can often either supply people or make good recommendations about whom to request and how to secure their help. Former developers and users of the legacy simulation may be able to recommend simulation domain experts.

Managing the V&V Effort

The V&V Agent is responsible of implementing the V&V plan. As such, the V&V Agent has a number of management responsibilities shown in the following table:

V&V Agent Management Responsibilities
• providing good cost estimates and resource requirements to the M&S PM
• keeping the V&V effort focused on essential technical activities
• coordinating with the M&S PM to select appropriate and available tools, methods, and techniques
• adapting V&V activities to address program changes when required
• coordinating with the M&S PM to obtain the necessary resources as needed
• locating appropriate personnel and providing adequate training when needed
• adhering to the simulation configuration management methods and products
• providing sufficient evidence to support the accreditation decision within available resources
• meeting goals and objectives specified in the V&V plan on time and within budget

Most successful V&V efforts use both informal and formal lines of communication and reporting to support these objectives (e.g., daily staff meetings, ad hoc problem-solving sessions, weekly status meetings).

Leveraging Configuration Management Resources

[44] See the special topic on Subject Matter Experts and VV&A for additional information.

One of the keys to maintaining the shelf life of a legacy simulation is a well-structured, well-maintained, workable configuration management system. Configuration management can ensure the integrity of the simulation products being housed, process problem reports and change requests, control changes, and provide continuity throughout the life of the simulation. From the perspective of both the V&V Agent and the Accreditation Agent, configuration management is essential for establishing the reliability and completeness of the simulation documentation. The foundation for both the V&V effort and the accreditation assessment of a legacy simulation is a thorough understanding of the simulation as it exists. This requires complete and accurate information of the simulation's past.

A simulation that has been used over a long period of time has frequently undergone a number of changes instigated by different Users for different reasons. Configuration management should ensure that these changes have been captured. The M&S Proponent should provide the V&V Agent with access to the information in the simulation's configuration management system. In turn, the V&V Agent should make sure all V&V documentation is prepared in accordance with configuration management guidance with respect to form and format and V&V with unique identifiers to distinguish them from those generated by other parties.

Tracking and Reporting V&V Effort Progress

Tracking is the process of evaluating the actual performance of the V&V effort with respect to the planned effort and comparing the costs accrued with the budget on a periodic basis. At the beginning of the V&V effort, the V&V Agent and M&S PM should determine the measurement data to be collected, the techniques to be used in their interpretation, and the reporting formats and schedules. Status reports should be produced regularly (e.g., monthly) on larger V&V efforts. Smaller V&V efforts may not require this type of tracking and performance measurement.

V&V Agent's Relationship with Other Roles

Information Exchanges

To understand what the simulation is capable of doing, the Accreditation Agent, User, M&S PM, Developer, and V&V Agent need a full description of the simulation's existing capabilities, limitations, and evidence of simulation accuracy and usability. To understand what the simulation needs to provide for the intended application, they also need extensive information about

- risks associated with using this simulation for the intended purpose
- data -- including data previously used in the simulation and new data being introduced for this application

- operators and analysts -- so the adequacy of supporting documentation (e.g., user manuals, tutorials) can be assessed

The table below shows the information exchanges between roles in the legacy simulation preparation process.

Information Exchanges between Roles						
Information	**User**	**VV**	**AA**	**PM**	**Dev**	**Prop**
Existing simulation	**R**	**R**	**R**	**R**	**R**	**P**
Existing simulation documentation	**R**	**R**	**R**	**R**	**R**	**P**
Requirements	**P**	**R**	**R**	**R**	**R**	
Accreditation decision	**P**					
Plans	**P**	**R**	**R**	**R**	**R**	
Modification Plans	**A**	**R**	**R**	**P**	**R**	***A****
Funding / Schedule	**A**	**R**	**R**	**P**	**R**	
Simulation conceptual model		**R**		**A**	**P**	***R****
Design(s)		**R**		**A**	**P**	***R****
Code		**R**		**A**	**P**	***R****
Implementation		**R**		**A**	**P**	***R****
Manuals		**R**		**A**	**P**	
Test plans and results		**R**		**A**	**P**	
V&V plans	**R**	**P**	**A**	**R**	**R**	
Verification results		**P**	**A**	**R**	**R**	***R****
Validation results		**P**	**A**	**R**	**R**	***R****
Accreditation plans	**A**	**R**	**P**	**R**	**R**	
Acceptability criteria	**A**	**R**	**P**	**R**	**R**	
Accreditation information needs		**R**	**P**	**A**	**R**	
Accreditation reports	**A**		**P**			
When version of simulation involved is under program configuration control.						
P: Produces the artifact or product						
A: Approves or authorizes distribution of the artifact or product						
R: Receives or uses the artifact or product						

Relationship with the User

The major purpose of the V&V effort is to provide evidence about the credibility of the simulation for the intended use and to identify problems with the modifications. The objective of the V&V effort is to satisfy the User that the simulation is fit for the intended use. This is usually achieved indirectly through the cooperative relationship with the

Accreditation Agent. However, the V&V Agent should look to the User to provide SMEs for various V&V activities (e.g., to ensure that the behaviors, representations, and performance of the required elements are within acceptable limits). The User should recognize that the V&V effort is a primary means for determining that the simulation will be able to satisfy the intended use and should be encouraged to participate in different V&V activities to stay abreast of the evolving status simulation.

Relationship with the Accreditation Agent

The V&V Agent serves as primary support for the Accreditation Agent by collecting evidence about the legacy simulation to be used in the accreditation assessment. The V&V effort should both illuminate the capabilities of the simulation and its conformance to the M&S requirements and identify its shortcomings, limitations, failures, and imperfections. The relationship between the V&V Agent and Accreditation Agent should be ongoing and cooperative so that both can be sure the evidence collected during the V&V effort will be sufficient to identify the capabilities and limitations of the simulation.

The Accreditation Agent makes the acceptability criteria available and defines the accreditation information needs that serve as the basis of the V&V effort. In turn, the V&V effort provides evidence in terms of the acceptability criteria regarding simulation fitness. Throughout the V&V process, the Accreditation Agent should be informed of results to ensure that the effort stays focused and there are no major surprises at the end that are difficult to reconcile.

Since accreditation is an activity that is repeated for each new use of the simulation, there is likely to be a series of Accreditation Agents who will need the information resulting from the V&V efforts conducted during original development and all subsequent reuses of the simulation. Because the quality and thoroughness of the V&V effort will have an impact on these future accreditation assessments, the V&V documentation should highlight the proven capabilities, limitations, constraints, and assumptions of the simulation.

Relationship with the Developer, M&S PM, and M&S Proponent

The M&S Proponent is the configuration manager of the legacy simulation. The V&V Agent interfaces with the M&S Proponent to obtain information about the simulation, about the configuration control measures in effect, and any configuration changes that involve the version of the simulation being considered for use. The M&S Proponent may also be asked to provide V&V and usage histories or identify sources for them. If the simulation is under configuration control, the V&V Agent should make sure all V&V findings, problem reports, and change requests are prepared in compliance with existing configuration management policies and submitted to the M&S Proponent for entry into the configuration management system.

In legacy simulation reuse, the Developer is responsible for making the modifications and the M&S PM is responsible for managing the modification effort. The M&S PM,

Developer, and V&V Agent should coordinate planning to ensure smooth and timely interactions, to establish respective areas of responsibility (e.g., who is responsible for conducting which tests), and to define the artifacts and documents each is to produce. The M&S PM should be involved in any discussions between the V&V Agent and Developer involving the exchange of information, data, software, tools, testing, etc., to prevent any possible misunderstanding concerning access and rights to specific products. The success of the V&V effort depends on access to a number of modification products (e.g., M&S requirements, conceptual model, software and hardware specifications, designs, software, drawings, data, tools, support systems, configuration management data, tests, and test results). The M&S PM should ensure these products are available when needed. In return, the V&V Agent should notify both the Developer and M&S PM when problems discovered and should provide recommendations for their resolution when possible.

Relationship with Others

Testing Activities

When the simulation is being modified or when a need exists for testing, the V&V Agent should coordinate with other participating testing activities (e.g., OT, DT) to share resources and avoid redundant efforts.[45] Both the M&S Proponent and User have the prerogative to bring in outside organizations to observe or evaluate the simulation, assist with the validation effort, test critical features and functions, or perform independent analyses to help determine the simulation fitness. Plans should ensure that all testing activities work together to share resources, leverage tests, and share information, reports, and assessment results.

Subject Matter Experts

SMEs are relied on throughout the V&V process to provide expertise in a variety of areas (e.g., operational doctrine, tactics, and procedures; software languages; data; physical and natural laws and relationships; hardware; etc.), in particular during requirements verification and conceptual model and results validation activities. SMEs can also help establish the validation testing requirements and identify “real-world” data used in results validation.[46]

Documentation Requirements

As simulation configuration manager, the M&S Proponent should oversee the collection and archival of essential VV&A information along with information about the simulation. (If not performed by the M&S Proponent, this should be performed by the V&V Agent.) The primary goal is to insure that an accurate, comprehensive record of the V&V

[45] See the reference document on T&E and V&V Integration for additional information.
[46] See the special topic on Subject Matter Experts and VV&A for additional information.

activities and the accreditation assessment is kept. The types of documentation, including the formats to be used, should be specified during planning and should comply with legacy simulation configuration management guidance.[47]

In general, documentation should be specific enough to demonstrate the rigor of the V&V effort and comprehensive enough to describe the overall V&V process that was executed. The basic criteria for information collection is to ensure that sufficient documentation is saved, in an appropriate format, so that a complete profile of status, product quality and completeness, and identified problems and risks can be generated from the information and data retained. The archival schema should allow for sufficient documents and data to be transferred based on demand, without overwhelming the recipient.

V&V results should highlight the proven capabilities and limitations of the simulation with respect to potential uses of the simulation. V&V information should be collected and archived for two reasons: accountability and reuse. One of the most important functions of a well-documented V&V effort is to provide a record of how and why decisions were made throughout the preparation of the legacy simulation for use. In general, for each step in the V&V process, the focus should be on collecting and archiving information that demonstrates

- simulation insights (capabilities and limitations)
- V&V methods and results
- problems and issues uncovered (and their resolution)

To facilitate the collection and archival processes, the V&V plan should define the V&V artifacts and documents to be produced, including level of detail, formats, and structures, and allocate time for their production throughout the V&V effort. It is much easier to record important information and events as they happen, as well as clarify ambiguities, than it is to try to go back after the fact and piece together what happened. These interim reports should be prepared for each major V&V activity or task, such as

- V&V plan (*Develop the V&V Plan* [p. 19])
- Risk assessment report(s) (*Assess V&V Risks* [p. 23])
- Requirements verification report (Verify M&S Requirements [p. 13])
- Simulation capability report (*Characterize Simulation Capabilities* [p. 17])
- Simulation conceptual model validation report (*Validate Conceptual Model* [p. 36])
- Design verification report(s) (*Verify Design* [p. 40])
- Data V&V reports (*Verify and Validate Data* [p. 27])

Field Code Changed

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[47] See the RPG template on Common VV&A Formats for additional information.

Field Code Changed

- Implementation verification report (*Verify Implementation* [p. 42])
- Results validation report (*Validate Simulation Results* [p. 30])
- V&V Report (Document the V&V Effort [p. 34])

The care with which this record is reported is also important. Providing accreditation support means having sufficient credible evidence to ensure good understanding of the capabilities and limitations of the simulation. High-level reports are not normally enough. Detailed information is often needed to fully evaluate the characteristics and capabilities of the simulation, and traceability is essential to demonstrate how fully the simulation can address the intended use. See Appendix D for additional information.

Factors Influencing V&V Cost and Resourcing

Cost Factors

Several factors determine the costs of validating and verifying a simulation whether starting from scratch with a new development, reusing a legacy simulation, or composing a simulation federation.

Application Risk. The risk a User is willing to accept when using a simulation is a primary driver of the V&V costs. Simulations that deliver information upon which decisions involving life or great financial impact require commensurately intense V&V effort to ensure the correctness of their results. Simulations whose use involves lower risks (e.g., demonstrations) can tolerate less intensive V&V effort. The type of application typically determines the potential impact and probability of that impact occurring (i.e., the application risk).

Application Complexity. The complexity of the intended use of the simulation determines the levels of effort required to build and prepare the simulation and to validate and verify it for that use. Application complexity describes the intricacy and, thus, difficulty of the user's use of the simulation. Application complexity comes primarily from the intended use and the interfaces of the simulation with the other things involved in addressing the intended use (e.g., humans, other simulations, other types of systems). Other factors such as reusability, required simulation quality, expected lifetime of the simulation, the need to meet different standards, and the acquisition strategy can all contribute to the application complexity.

Accreditation Authority Requirements. Since V&V activities primarily produce information for accreditation, the amount and type of information that an accreditation authority requires to make their accreditation decision is a function of the application risk and complexity. However, the needs of different authorities vary and these variances can drive the V&V effort needed to deliver the required information.

Simulation Complexity. The complexity of a simulation is a function of the application complexity and may substitute for it in some cases. Alternatively, program size, expressed in various units, may be considered since very little agreement currently exists on a consistent definition of complexity. Despite this, the linkage between simulation complexity and estimates of the V&V costs remains tenuous.

Availability of Referent Information. Referent data is critical to validation activities focused on evaluating simulation accuracy. The knowledge that the referent provides creates the yardstick against which to measure simulation accuracy. Referent information can come from actual observations (e.g., data collected from test ranges), theory validated against actual observations (e.g., laws of motion, laws of thermodynamics), validated simulations, and subject matter expertise. The availability of this information can be one of the biggest drivers of simulation validation costs if it does not exist in some easily accessible form. Predicting the costs of collecting and preparing referent data may be very difficult. When faced with the absence of referent data, the V&V agent must choose the sources that both satisfy the user's demands and the program's budget. In some cases, the V&V agent may need to raise the need to invest in collecting referent data to the appropriate decision maker level.

Availability of Simulation Information. If given adequate and unambiguous requirements and adequate referent information, collecting information about the simulation's actual capabilities and characteristics represents an important part of the V&V effort. This information can come from such sources as existing documentation, prior V&V efforts, or prior testing results. If existing documentation is inadequate then the simulation must be characterized through testing or reverse engineering. Collecting information can have three components: the expense of buying information, the cost of reconstructing unavailable information, and the costs incurred when forced to replace a relatively inexpensive V&V technique with a more expensive one. Possible information sources include static descriptions of a simulation (e.g., conceptual model), behavioral descriptions of the simulation, observations of the changes in output when the input data are changed (along with statistical analysis of those observations), reverse engineering and analysis of the mathematical description underlying the simulation (be careful that that was what was implemented).

Availability of M&S Requirements Information. A simulation can only be validated to the degree to which the M&S requirements have been articulated. The completeness, accuracy, and comprehensibility of this articulation can affect V&V costs considerably. Inaccurate or inconsistent requirements returned to the User for correction will need to be reverified. Vague or incomplete requirement descriptions increase the V&V burden when clarification of requirements is accomplished through iterative refinement and verification.

Personnel Resources. The experience from actual simulation programs has shown the experience and expertise of the people performing the V&V are important in determining the costs. Practitioner expertise will be a V&V cost driver especially for very complex simulations. The number of personnel involved can also significantly impact costs due to such factors as coordination inefficiencies, communications overhead and team cohesion.

Development Process. This factor includes both the processes employed in simulation design and implementation and the processes used to perform the V&V activities. Most software system cost estimation techniques take development process factors (e.g., development methodology type, development process maturity, commitment to development methodology) into account in their estimates. The process maturity and commitment to the V&V methodology can affect the V&V costs in much the same way and, thus, must be factored into the estimation of V&V costs.

Implementation and Execution Environment. Such factors as the execution platform, development language and environment and platform volatility can affect development costs. These factors can also impact V&V costs especially in those situations that require reverse engineering to sufficiently characterize the simulation's capabilities. Even when validation only requires results testing, the V&V team must adequately understand the execution environment to distinguish the effects of the model from those of the execution environment.

Every V&V effort has those aspects that make it unique. This fact makes providing a general equation that meaningfully assigns weights to these cost factors difficult to impossible. Most sources agree about the importance of application risk, application/simulation complexity and the availability of information to determining V&V costs. Thus, any estimates of V&V costs must take these factors into account. A very limited amount of work has been done to create a parametric model of simulation V&V costs [43] but far more research is necessary to mature this aspect of V&V practice. However, the software engineering community has achieved some success in developing reasonably accurate cost models for software system development. These achievements can both encourage and guide the further maturation of V&V cost estimation.

Controlling Costs

Leveraging

All existing simulation documentation, including its technical specifications, prior V&V reports, data, and other evidence, should be leveraged to reduce the cost of the current V&V effort. The existing documentation will need to be updated to include the new capabilities being added to the simulation and additional information about the unchanged portions of the simulation. Tools and support software and systems such as compilers, configuration management systems, CASE tools, special test equipment, etc., that have been used in the past will be needed to support the modification. These may be available through the original Developer or the Developer doing modifications and, in either case, should be shared with the V&V Agent if possible. If sharing is not possible, the cost of obtaining a usable set of tools and support systems for the V&V effort depends on several factors.

Another leveraging opportunity comes from assessment of past validation efforts to see what can be used. Validation data, scenarios, use cases, and tests should be reviewed

to see if they can be used for the intended application. Even if they cannot be adopted wholesale, they can be used as patterns.

V&V Funding Level

If the Accreditation Agent and User decide the V&V Agent's V&V cost estimate is unreasonable, the V&V Agent will need to modify the V&V plan, tailor the V&V activities, and re-estimate the costs until the User and Accreditation Agent are satisfied. The Accreditation Agent, in particular, should be aware of the impact on the ability of the V&V effort to address the accreditation information needs. Failure to adequately address the accreditation information needs will increase the risks involved and may adversely affect accreditation.

Balancing Cost and Risk

In planning, the V&V Agent needs to find a viable balance between the cost of doing [each] V&V [task] and the level of risk associated with not doing [each] V&V [task]. The V&V Agent has to determine where the point of diminishing returns occurs and should try to stop just short of passing it. Whatever cost estimating process is used should have built-in checks and balances so the User, Accreditation Agent, or M&S PM can readily see what the V&V effort is proposing to do for the assigned budget.

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select menu*: RPG Core Documents*, select item: “V&V Agent Role in the VV&A of New Simulations”

select menu item: “Key Concepts”

select menu*: RPG Reference Documents*, select item: “T&E and V&V Integration”

select menu*: RPG Reference Documents*, select item: “V&V Techniques”

select menu*: RPG Reference Documents*, select item: “V&V Tools”

select menu*: RPG Special Topics*, select item: “Conceptual Model Development and Validation”

select menu*: RPG Special Topics*, select item: “Data V&V for Legacy Simulations”

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select menu*: RPG Special Topics*, select item: “Foundations for V&V of the Natural Environment in a Simulation”

select menu*: RPG Special Topics*, select item: “Measures”

select menu*: RPG Special Topics*, select item: “Requirements”

select menu*: RPG Special Topics*, select item: “Risk and Its Impact on VV&A”

select menu*: RPG Special Topics*, select item: “Subject Matter Experts and VV&A”

select menu*: RPG Templates*, select item: “Data Quality”

select menu*: RPG Templates*, select item: “Common VV&A Formats”

In the web-based version of this document, the appendix below appears as a hot link in the section on Collect Simulation Information.

Appendix A: Legacy Simulation Information Sources

Where to Find Information for a Legacy Simulation and What to Do with it?

The following table [derived from Muessig, et. al] provides some insight into the issues revolving around simulation credibility and accreditation, what types of information are typically used to address the issues, and where that information might be found. This collection of information is based upon the experience of the Joint Accreditation Support Activity (JASA) in conducting accreditation support for acquisition programs. Legacy and modified legacy simulations were the M&S tools of interest in all of these programs.

Items Required	Item Description	Typical Sources
Credibility Issue: Does the simulation do what you need it to do?		
• Functional breakdown • Description of model	Describes what the model actually does including • M&S functions and relationships between functions • level of fidelity at which each function is modeled • function level input and output (I/O) and I/O relationships between functions • hardware, software and training needed to operate the model properly and interpret the output correctly	• user documentation (user programmer, and analyst manuals) • software design documentation, possibly including data flow diagrams • conceptual model documentation
• Limitations due to assumptions and errors	Describes model assumptions and known errors, and assesses their impact on model use. The resulting limitations should be correlated with each of the functions in the functional breakdown, but may also be useful at the overall simulation level. Should identify assumptions and/or errors of each M&S function (or of the model as a whole) that are implicit or explicit in the model's design and/or coding, as well as the implications of these limitations on appropriate or acceptable uses of the simulation.	• software design documentation and user documentation are the most typical sources of inherent assumptions and limitations arising from the algorithms used • configuration management databases are useful for known errors • change requests • some assumptions and limitations may be found in verification or validation reports but may not be explicitly stated as an assumption, limitation or error

Items Required	Item Description	Typical Sources
Credibility Issue: Do you have confidence that the simulation is being run properly?		
• Simulation portability across platforms (computer hardware and operating system suitability)	Test results that show that the hardware and operating systems used to host the simulation (if different than that used to develop the simulation) will allow it to run correctly and produce consistent results across platforms.	• usually found in the user documentation associated with the simulation or can be obtained from test results when documentation is not available
• Operator qualifications	Information to demonstrate that the operators have the expertise and knowledge to properly set up the simulation, execute it, and operate all associated tools and utilities. Typical information includes experience with the specific model being used, formal training on the model, experience with the hardware, software, and interface devices being used.	• biographies or interviews with the operators
Credibility Issue: Can you convince others of your interpretation of simulation outputs?		
• Analyst qualifications	Information to demonstrate that the analysts using the simulation have the expertise and knowledge to properly generate the input data and interpret the outputs. Typical information includes experience with the specific model being used, formal training on the model, experience in performing similar analyses and experience or training in simulation-based analysis techniques.	• usually gathered from biographies or interviews with the analysts or may be found in prior accreditation assessment reports
• Demonstration of pre- and post-processor acceptability	Information that shows that any auxiliary tools and utilities used to format or load input data, or to convert, record and visualize model outputs are suitable for the intended purpose(s). The type of information usually presented includes descriptive documentation of the tools and utilities being used for these purposes.	• user documentation associated with the simulation may list tools and utilities that are comparable with it • user documentation for the tools and utilities may contain information that will aid the determination of tool compatibility with the simulation
How much confidence do you have in the accuracy of the software?		

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Items Required	Item Description	Typical Sources
• Software development process description	The process description should include: • description of the development paradigm and how it is being implemented (including the use of CASE tools) • a logical process for defining tracing, and testing requirements throughout development • configuration management during the development process • adequate provision for documentation of all of these activities	• software development plan or a configuration management plan that outlines the development process used • If the development is underway, these plans should describe the process currently being used.
• Software development resources description	The resource description should include: • a description of the hardware environment and the software engineering tools that will be/were used • qualifications of the personnel who will/did code the software and perform configuration management functions • who will be/was responsible for production of key documentation and testing • history of similar simulation development experience	Information should be provided in the software development plan or other management plans. If not documented, discussion with the software developers and managers is necessary to obtain as much information as possible, even if anecdotal. SEI Capability Maturity Model (CMM) evaluation report can provide evidence of simulation development qualifications.
• Software development artifacts	Simulation development artifacts that provide evidence (usually documentary in nature) that software development is actually being implemented in accordance with the guidelines and specifications called out in the software development plan (or its equivalent). Documentary artifacts should comply with known (or acceptable) standards and practices for format, content, currency and applicability to the current versions of the software.	• standard simulation documentation that reflects the current state of the software and that conforms to known standards of information content (e.g., configuration management histories and logs). • model documentation (user, programmer and/or analyst manuals) • software design documentation • documented set of requirements and conceptual model

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Items Required	Item Description	Typical Sources
• Software development results	V&V results include all evidence that the code has been developed according to the design and is free of critical errors, including reports from • design reviews • code walk-throughs • regression testing on model changes • software testing • supplemental V&V efforts of previous simulation users.	• requirements trace reports • reports of design reviews, peer reviews, and/or logical reviews • code walkthrough reports • software problem change request logs • module software test reports • subsystem software test reports • system software test reports
• Software management process description	The process description should include • a description of the post development management of the software • processes for documenting, implementing, tracking and testing simulation changes resulting from either requirements changes or software errors Processes should also exist for keeping all software documentation current with the software.	M&S life cycle activities should be addressed in • software management plan • configuration management plan • V&V plan • accreditation support plans Simulations developed within the Army should have a Simulation Support Plan (SSP).
• Software management resources description	The resource description should summarize the nature and extent of resources currently being applied to simulation management and support. The information should indicate whether sufficient funding and experienced personnel are being applied to ongoing documentation support, configuration management support, regression testing, user group support, training, technical support, etc.	Information should be included in management plans. If this information is not in existing documentation, discussion with the model managers and/or software developers is necessary to obtain as much of this information as possible, even if anecdotal.
• Software management artifacts	*Artifacts* refers to the evidence (usually documentary in nature) that software maintenance is actually being conducted in accordance with the guidelines and specifications called out in the simulation management plan (SMP), SSP, or its equivalent.	• configuration management database status reports, software change requests (SCRs) and/or system trouble reports • up to date model documentation (users, programmers and analysts manuals) • Configuration Control Board (CCB) and user group meeting minutes • updated software design documentation

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Items Required	Item Description	Typical Sources
• Post-development software V&V results		• software program change request (SPCR) logs that correlate V&V results with specific versions of the software • alpha or beta test reports for both new requirements testing and regression testing • specific verification reports for the simulation version being used • history of successful usage in similar applications
How much confidence do you have in the quality and suitability of input data obtained from outside sources?		
• Data quality profile[1]	A body of metadata (data about the data) that describes the data or database, its source, specifications, intended use, history, and method of collection. Metadata elements should exist at the database, data element, and data value levels.	• metadata elements should be available from the data producer or may exist in the same archives that contain the database itself
• Independent assessment of data quality	An independent assessment is prepared by the data user when the data quality profile is inadequate, incomplete, or does not exist. This assessment addresses the key metadata elements in the data quality profile.	• Information that indicates the quality of test data can generally be found in documents such as test plans, laboratory procedures, calibration records, test records, etc • Information that indicates the quality of data collected through surveys or monitoring operations can generally be found in data collection plans, reports, and raw notes

[1] See the Data Quality Templates for additional information.

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Items Required	Item Description	Typical Sources
• Data manipulation verification	This item refers to the verification of any data manipulation done by the user. Data manipulation includes operations such as editing, subset selection, merging, aggregation, transformation (from one coordinate convention to another, for example, or one set of units to another), estimation, interpolation, etc. Verification includes any activities that are done to ensure that the data manipulation steps are correct and do not introduce unknown errors.	• Verification of data manipulation procedures may be documented in verification reports (when done in conjunction with simulation development). • data manipulation verification performed as part of the simulation accreditation process should be included in the accreditation report. Documentation should describe the verification techniques that were used.
How much confidence do you have in the quality and suitability of self-generated input data?		
• Quality assurance process for self-generated data	An assessment of the process, equipment, tools, instrumentation, etc. used in generating the data. This assessment should generate information similar to that included in the critical metadata elements of the data quality profile.	• Information that indicates the quality of test data can generally be found in documents such as test plans, laboratory procedures, calibration records, test reports, etc. • Information that indicates the quality of data collected through surveys or monitoring operations can generally be found in data collection plans, reports, and raw notes
• Description of data quality assurance resources for self-generated data	Refers to the verification of any data manipulation done following receipt of the data by the User. Data manipulation includes operations such as editing, subset selection, merging, aggregation, transformation (e.g., from one coordinate convention to another, from one set of units to another), estimation, interpolation, etc. Verification of data manipulation includes any activities that are done to ensure that the data manipulation steps are correct and do not introduce unknown errors.	• verification of data manipulation or transformation procedures should be documented in M&S verification reports • other data manipulation may be reviewed and verified as part of the M&S accreditation process and documented in the accreditation assessment report Documentation should describe the verification techniques that were used.

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Items Required	Item Description	Typical Sources
How much confidence do you have in the simulation outputs?		
• Benchmarking results	These document the results of comparisons between simulation or simulation component outputs and those of a "standard" or widely accepted, comparable simulation or component. Benchmark results should include • the name and source of the standard simulation • why it is (or should be) considered a "reference" simulation • which parameters between simulations (or simulation components) were compared (and why) • what the results of the comparison were • what these results imply about the credibility of the outputs from the simulation under review Benchmark simulations generally possess greater credibility than the simulation (or component) under review and may be characterized by a "stamp of approval" from a recognized authority or professional organization.	• benchmarking results are usually found in either a validation report, a briefing that describes the results of the comparisons, or an accreditation support package (ASP)[2] These reports would generally be prepared by previous users of the simulation. They might also be available through the model manager or in M&S repositories (e.g., DoD and individual Service Modeling and Simulation Resource Repositories [MSRR]). If these results are for a previous version of the simulation, there also should be discussion of changes between that previous version and the version under consideration, and the implication of those changes.

[2] The ASP is used in the JASA accreditation process and the AF Toolkit.

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Items Required	Item Description	Typical Sources
• Face validation results	Describe the results of subject matter expert opinions about simulation realism and accuracy. This should be based on a structured review of simulation (or component) outputs, sensitivities, and/or design. When face validation is a review of the simulation design, the documentation should state whether the representations are realistic and whether any assumptions that underlie the design are acceptable from the perspective of the intended use. Documentation should describe which aspects of the simulation were reviewed (and why), who participated in the review, why one should trust their opinions (e.g. qualifications of the reviewers), what the results of the review were, and what these results imply about the credibility of the simulation.	• face validation reports, ASPs, or accreditation assessment reports (when the face validation was done as part of an accreditation assessment) • simulation design validations may be reported in a design verification report (either a formal report or a briefing). These reports would generally be prepared by previous users. They might also be available through the model manager or an M&S repositories If these results are for a previous version of the simulation, differences between that previous version and the version under consideration and the implication of those differences should be considered.
• Results validation documentation	Describes the results of comparisons between simulation (or simulation component) outputs and data collected from tests or from operation of the real system(s) or process(es) being simulated. The documentation should include a description of the source data used in the comparison, from where and how it was obtained, and why it should be considered representative of the real world. Issues relating to data quality (e.g. instrumentation accuracy, calibration, test scenario realism, etc.) should be addressed in the validation report. The correlation between simulation outputs and real world data should be stated in quantitative terms if this is possible with a qualitative explanation of what the quantitative measure implies. Anomalies and their impact on model usage should be explained.	• Results validation is typically documented in a validation report, accreditation assessment report or ASP. • In some cases, results validation might be documented with an annotated briefing prepared by the simulation developer or previous users, but may also be available through the model manager or M&S repositories. If these results are for a previous version of the simulation, differences between that previous version and the version under consideration and the implication of those differences should be considered.

Obtaining Oral Testimony

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Locating information about a legacy simulation often involves talking with the people associated with its development, its maintenance, or its usage. One key is to ask the right questions.

- Engineers/analysts/programmers/scientists doing the simulation development tend to under-report the amount of V&V they have done, primarily because they tend not to use the terms “verification” and validation.” They tend to perform the kinds of tasks that V&V and Accreditation Agents call verification and validation as just a part of sound engineering practice. If asked what verification or validation has been performed, they may say, “nothing.” But if asked what was done to ensure that the simulation satisfied the specifications, performed as expected, or provided an appropriate level of realism, they will provide engineering notebooks describing tests or computer displays showing comparisons between the simulation and test data.
- Those who maintain a simulation almost always have a system for managing changes and maintaining control of the simulation even though it may not be called “configuration management.” If asked about “the configuration management plan,” they may say there is none; if asked how changes are tracked, they often describe a well thought out, practical system for documenting changes and model versions.

Another key is to ensure there is documentation to corroborate the discussion.

- Conscientious Developers often keep wonderful engineering notes that may be undervalued because they are not formally documented. However, such notes may be more useful than more formal model documentation because they provide more technical content.
- Managers or users may not be able to provide specific technical information. They may not have complete knowledge of the V&V tasks performed, software engineering practices followed, the SEI CMM level, etc.

Simulations in the Military Acquisition Process

If the item being modeled is a military system, and the simulation was developed as a tool as part of the acquisition process, there are several possibilities for gathering information on the simulation.

- The simulation documentation and V&V information may have been deliverables in the contract for development of the military item. The contracting officer’s technical representative should have a copy of all the deliverables under the contract or know where to get them.
- If a government agency had oversight (e.g., technical direction agent [TDA]), they may have been doing testing on the simulation including comparisons with test data as the acquisition program progresses. This can be a tremendous

source of validation results and understanding of the assumptions and limitations of the simulation that may not be written down anywhere. Interviewing these folks can be very fruitful. It is also often the case that the government team has the most corporate knowledge of the simulation because there is often less turnover on the government teams than on the contractor teams.

- There may also be a simulation working group or M&S integrated product team (IPT) whose minutes or informal records can be a good source of information.

Another source of simulation information may be the system being simulated. During the development of a complicated system (military or otherwise), modeling and simulation is often employed as a tool. Before expensive tests are conducted, simulations may be used to make pre-test predictions. The M&S predictions may be included in the data presented at test readiness reviews. In addition, simulations may be run after the test using the actual test conditions to compare to the test data. This may be done specifically for simulation validation, or simply to help the Developer understand what happened in the actual test. Results of these comparisons may be included in the test readiness after action reports.

If the simulation is of an actual item being developed (military or otherwise), a review of the simulation may be held as part of the preliminary design review (PDR) or the critical design review (CDR) of the actual item. Most companies and organizations keep archives of presentations given at PDRs and CDRs and have careful records of conclusions reached at these reviews. This can be a very useful source of documentation of the simulation itself, results of any V&V conducted, and conclusions about the maturity and of credibility of the simulation by the review participants.

In the web-based version of this document, the appendix below appears as a hot link in Support Simulation Selection.

Appendix B: Selecting a Legacy Simulation

The User may decide to use a particular legacy simulation because they have prior successful experience with that tool. This experience builds the credibility of the simulation as well as reducing the training overhead associated with using a simulation with which the user is unfamiliar. If the User only wants to use their existing simulation to address a new problem then no selection function need be performed.

If, on the other hand, the User sees several legacy simulations as viable candidates to provide the information they need then they must execute some selection function. This function should involve the Accreditation Agent and the Program Manager if they have been selected. The project may not need a Program Manager if the User does not anticipate expending sufficient resources for the discovery or modification activities to warrant the management overhead. However, if the User wishes to explore a new problem area with an existing simulation then they should appoint someone to fill the Accreditation Agent role to insure that they sufficiently understand the simulation's mapping into their problem space.

Choosing a legacy simulation from a set of candidates involves a cost-benefit analysis, either formal or informal. The primary benefits that using an existing simulation brings include

- demonstrated capabilities of the existing simulation
- credibility gained from the direct experience of the user successfully applying an existing simulation to related problems
- credibility gained from the direct experience of others trusted by the user in their successfully applying the legacy simulation to related problems
- support investment minimized by an existing maintenance, control and help desk infrastructure
- discovery and training investment minimized by an existing documentation package describing simulation capabilities and use history
- support and discovery investment minimized by the available resources of an existing trusted user community
- training investment minimized by the existing direct experience from using a familiar simulation
- development investment and schedule minimized by the use of an existing simulation

Each of these benefits can also be expressed in terms of the financial and schedule savings that they offer. For example, a simulation with a well-documented pedigree minimizes the effort required to assess that simulation's capabilities and hastens the accreditation effort. Documentation that permits direct accreditation assessment can completely eliminate the burden of the entire discovery effort.

The primary costs associated with using a legacy simulation come in the form of actual financial costs and schedule impact. The sources of these impacts are associated with the efforts to

- discover an unfamiliar simulation's capabilities if not sufficiently documented or available from the existing user or developer community
- change or add capabilities to an existing simulation to suit the new purpose
- validate the modified legacy simulation
- train users to effectively operate an unfamiliar simulation or unfamiliar parts of a familiar simulation
- provide local maintenance and support for an unsupported or modified simulation

The User will always need to make some investment and allocate some time in their schedule to accredit and prepare a legacy simulation for a new purpose. Those costs remain constant in the legacy use process and could serve as a measure of the minimal costs to compute relative magnitude of the other investments if desired.

The Accreditation Agent should assist the User with this analysis. If the need for modification or a significant discovery effort becomes a heavily weighted factor then the Program Manager should also assist in the selection process since they will be responsible for managing the execution of that effort.

Above all, the selection process must carefully analyze the balance of the costs and benefits, even if they are only estimates. For example, a simulation with a well-documented pedigree may seem an attractive selection if the pedigree is considered alone but any costs of modifying it may far exceed the costs of discovering the capabilities of a simulation that may need less modification. The selection process should also weight the impacts of financial and schedule costs appropriately. A User pressed for quick answers to critical questions may defer financial costs for reduced schedule. Likely, both factors will play some part in the selection but have different weights for different situations.

The selection analysis should also consider the flexibility of the purpose in the decision. One simulation may enable the User to achieve eighty percent of their objectives with no modification whereas another simulation may permit achieving ninety five percent of the User's objectives but require a huge financial and schedule investment to add the needed capabilities. When dealing with an unfamiliar simulation, encouraging the User

to explore a very small sample of their questions through the capabilities of the unmodified legacy simulation will provide valuable information at a minimal cost. This exercise will familiarize the User with the tool and give some information about where the simulation may require added representational capabilities. It will also give the User the opportunity to tailor their requirements to better suit the available tools.

The credibility of an existing simulation to the User and their customers may carry the most weight in its use. The strongest credibility comes from direct use by the User with the next strongest weight coming from the successful experiences of others that the User trusts as good sources of that information. However, care should be exercised when evaluating the applicability of prior experience to a new problem. The experience should come from problems whose examination requires simulation representations closely related to the new problem. While this advice seems obvious, many subtleties lie in using simulated representations. For example, a credible simulation of nuclear effects may provide very poor information of the dispersion of contamination if it models the weather and terrain poorly.

The value of an existing support infrastructure associated with a legacy simulation is often overlooked and discovered long after making a selection decision. The support for a legacy simulation comes first from the M&S Proponent of simulation program. The M&S Proponent's support is very important as they will likely serve as the source of much of the simulation's documentation and experiential base. The simulation's developer can also play an important role if they are still available. Finally, the support from an existing user base can serve many purposes including as the sources of capabilities, training, usage, and maintenance information. Further, a broad user base and an active proponent can help to minimize execution and representation faults through an ongoing feedback and response process.

In the web-based version of this document, the appendix below appears as a hot link in the Construct the Plan section of Develop the V&V Plan.

Appendix C: Insights into Tailoring V&V Activities for Legacy Applications

The following discussion is provided to help plan the V&V process in the most cost-effective and efficient way. Two general cases are discussed – when the legacy simulation will be used ***as-is*** and when the legacy simulation will be ***modified***. In both cases, the V&V effort should be tailored to address the needs of the current application based on the guidance provided by the Accreditation Agent, User, and M&S PM.

As-Is Reuse of a Legacy Simulation

When there are no source code changes involved, the V&V effort involves three basic activities: providing V&V information on the existing simulation, data V&V, and results validation. The scope of the V&V effort depends on the completeness and correctness of the information about the existing simulation and the need for new data. In any situation, emphasis should be on focusing or tailoring the V&V effort on those activities that can provide essential information to support the accreditation process.

As-is reuse with adequate information available and no new data required

The minimum case is when no source code changes are required, no new data sources are needed, there are minimal changes in the M&S requirements, and the simulation has an adequate set of documentation (e.g., development artifacts, simulation documentation, user reports, VV&A history). In this case, the User will still have to

- develop scenario(s)
- review existing M&S requirements and their associated measures and acceptability criteria to see if they are adequate for the current application
- define new M&S requirements
- obtain data
- revise the conceptual model to include new scenarios and M&S requirements (e.g., provide information on errata sheets)
- revise or develop new tests to test the implementation for the current application

At a minimum, the V&V effort should involve the following tasks:

- **Review Existing Simulation Information** – to ensure the information is complete and correct and adequately identifies existing simulation capabilities and limitations

- **Verify M&S Requirements** – to ensure the scenarios and new M&S requirements adequately reflect the needs of the application and are appropriately addressed in the simulation
- **Validate Revised Conceptual Model** – to ensure the scenarios and M&S requirements have been added properly and can be correctly represented in the existing design and implementation
- **Verify and Validate Data** – to ensure the data obtained are appropriate for use in the simulation and address the needs of the current application
- **Verify Test Plans** -- to ensure the tests accurately and completely address the needs of current application (e.g., new M&S requirements and scenarios)
- **Validate Results** – to ensure the results of the implementation are consistent with prior usage and fit the needs of the current application.

The information reviews and testing are V&V activities even if they are performed in the absence of a V&V Agent. It does not matter who performs a particular V&V activity, just that the activity is performed and documented and the results are provided to the Accreditation Agent and included in the simulation's VV&A history.

As-is reuse with adequate information available but new data is required

When new data sources are involved (e.g., previously used data sources are not authoritative for the current application, previously used data sources cannot provide necessary data), the same activities would be involved but the scope of the effort would be increased to evaluate the effect of the new data. New data sources and their data need to be verified. Existing data structures and preparation techniques need to be checked to ensure they are adequate for the new data. Existing data transformation algorithms should be checked to ensure they operate properly with the new data (and produce accurate results), and new algorithms should be validated and checked to ensure they work correctly with the existing simulation design and implementation. Data verification and validation before and during testing and results validation should focus on the quality of the new data, their ability to fit the needs of the application, and their appropriateness for use in the simulation.

As-is reuse with inadequate information

When essential information about the existing simulation is missing, the V&V effort may be expanded to include tasks to recapture this information. Regression testing may need to be performed to capture information about a specific aspect of the simulation. Development artifacts (e.g., conceptual model, designs) that were not verified or validated for the existing simulation may need to be to provide necessary information for the current application (e.g., validating the conceptual model of the existing simulation may help identify new M&S requirements and new data needs). The key is to focus only on obtaining information that is essential for the current application, not to ensure complete documentation of the existing simulation.

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Modification of a Legacy Simulation

Modification is done to ensure the simulation can address the M&S requirements of the current application or to accommodate hardware changes. Normally, a Developer implements the changes and, when the modification is of major size or importance, an M&S PM manages and oversees the effort. For proper configuration control, modification should be done in an organized manner, reflecting the phases of a new development. New M&S requirements are defined and refined, critical deficiencies are identified (determining what modifications are to be made), and the modification effort is planned. The conceptual model and designs should be revised to include the changes being made. The code is modified and tests are done to ensure the changes are correct, accurate, and sufficient to address the needs of the current application. In addition, tests should be done to ensure that the modification has no negative impact on the unchanged parts of the simulation.

As with the V&V effort for a new simulation, the V&V effort for a modified simulation should be conducted in coordination with the modification effort. The scope of the effort will depend on the size and scope of the modification (i.e., the amount of difference involved in both code and data). Each of the basic V&V activities may involve additional tasks. For example, new M&S requirements may need to be traced throughout, beginning in requirements verification and continuing through conceptual model validation, design verification, code implementation and testing. During the conceptual model revision, new M&S requirements can affect the acceptability criteria, scenarios, and the level of fidelity of associated representations, data, and possibly the timelines associated with subsequent preparation phases. During the design modification, M&S requirements can affect timing and sizing, necessitating changes in algorithms, data, or data preparation. During implementation and testing, new M&S requirements should be traced through to the code and tests to ensure they are being adequately represented and tested. During results validation, new M&S requirements should be traced to ensure that they are adequately addressed by the revised behaviors, representations, and algorithms; that errors and deficiencies are detected and corrected; and that the acceptability criteria and essential measures are satisfied.

Because many legacy simulations are tightly coupled architecturally, there may be a high level of uncertainty of how the changes will ripple throughout the simulation. Modifications in one part of a simulation may cause changes in the performance of another part. Because object-oriented (OO) design tends to limit the interactions between sections of a simulation, the impact of changes in one section are better controlled than in more standard functional designs. Therefore, depending on the type of implementation, the V&V effort may be able to focus primarily on areas of the simulation being modified or may need to review and assess the unchanged parts as well. The extent to which unmodified code needs to be assessed may not be determined until conceptual model validation.

Modification may also be needed when data changes are significant enough to impact the design or implementation of the simulation (e.g., the overall data model is changed, new data models are added, data availability forces modifications of algorithms). When the underlying data model is changed, there will be significant ripple throughout the simulation. Every V&V activity will include tasks to verify that the data model is accommodated adequately in the design, implementation, and development and validation testing. The impact of adding new data models or revising old ones can be felt throughout the simulation and can result in expanding the V&V effort to address even unchanged parts of the simulation.

In the web-based version of this document, the appendix below appears as a hot link in the Documentation Requirements.

Appendix D: VV&A Archive Information

The following table lists some of the major artifacts and products to be archived for future VV&A efforts.

Information to Consider Archiving for VV&A	
	Artifacts and Products
M&S Requirements	• definitions • metrics, measures,[1] and acceptability criteria • requirement trail through the simulation conceptual model and design to code • relationships to specific entities, processes, behaviors, events, or outputs • modifications/revisions required and accomplished
Planning	• problem definition and objectives • M&S development plan • V&V plan • data V&V plan • accreditation plan • modifications/revisions required and accomplished
Simulation Conceptual Model	• validated annotated conceptual model • behaviors and interactions[2] and associated data • sources of real world knowledge, data • verification techniques and results (e.g., data sources, interactions) • validation process and results (e.g., behaviors, conceptual model) • modifications/revisions required and accomplished
M&S Design	• annotated simulation designs, preliminary and detailed • design entities (e.g., objects, attributes, parameters) mapping to simulation conceptual model elements, objectives, requirements • verification techniques and results (e.g., functionality, data) • modifications/revisions required and accomplished
Implement and Test	• verified code • verification techniques and results (e.g., data, code) • testing techniques, data, scenarios (use cases), and results • data flow analysis • data validation techniques and results • results validation techniques, data, algorithms, scenarios (use cases), and results • modifications/revisions required and accomplished

[1] Measures of Performance (MOPs), Measures of Effectiveness (MOEs), etc. used to quantify each requirement. See the special topic on Measures for additional information.

[2] For example, the interaction of wind over the wing of an aircraft causing the aircraft to follow the laws of physics or tracing how command and control decisions are made (working backward from decision tables through to the sources of the information).

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Information to Consider Archiving for VV&A	
	Artifacts and Products
Prepare for Use	• accreditation information needs • accreditation assessment process, results, and recommendations • accreditation report • modifications/revisions required and accomplished • constraints, limitations, assumptions associated with the application • results of execution

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