

The M&S PM's Role in the VV&A of New Simulations

RPG Core Document

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¹ This document replaces the 5/15/01 version. It contains minor editorial and formatting changes.

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VV&A Responsibilities and Challenges

The objective of this document is to describe the M&S Program Manager's (PM) role and interests in the verification, validation, and accreditation (VV&A) of a new simulation. The M&S PM is in charge of the programmatics and managerial aspects of a simulation development. The M&S PM needs to identify the sources of greatest risk to the development effort and should work to control them as much as possible. Specific responsibilities include

- identifying the development paradigm,¹ in coordination with the Developer
- directing all aspects of the development, schedule, budget, contracting, and risk management²

The M&S PM is concerned that the available resources are focused on bringing the project to a successful conclusion and that the simulation has credibility within the User community. The V&V effort can help the M&S PM avoid costly rework in later phases of the development process by identifying problems early. The M&S PM has the opportunity to focus verification and validation (V&V) resources on high-risk development issues and increase the probability of success in the development of the simulation. Although the role is primarily that of monitor of the M&S program, the M&S PM can participate in the V&V effort in other ways as well, as shown in the Roles and Responsibilities³ table discussed in "Key Concepts."⁴

How Does the M&S Program Manager Impact VV&A?

The M&S PM has a responsibility to deliver a simulation that is complete and correct, on time, and within budget. Risks exist in every M&S program that, if left unaddressed, can prevent the program from achieving its objectives. The VV&A process is a risk mitigation tool in which the V&V effort serves as the tool and the accreditation process serves as the driver. The M&S PM can take advantage of the VV&A process to eliminate problems and maintain quality.

An M&S program has many claimants on resources (e.g., requirements definition, conceptual modeling, design, implementation, testing, accreditation), including the V&V effort. The M&S PM should resource V&V activities within the time and budget available to the project. In most cases of new simulation development, the demands for resources easily outstrip the resources available. Part of the "art" of being a successful M&S PM is learning to effectively balance resources to meet the most critical needs within the program. This can be true for small projects as well as large. Balance in

¹ See the special topic on Paradigms for M&S Development for additional information.

² See the special topic on Risk and Its Impact on VV&A for additional information.

³ See the diagram on Typical Roles and Their Responsibilities for additional information.

⁴ See the Key Concepts for additional information.

resource allocation, regular risk assessments, and focus of V&V assets are important to successful V&V effort.

For V&V assets to be successfully deployed, the critical high-risk aspects of the program need to be identified. Risk assessment⁵ is an important mechanism for discovering high-risk aspects. These aspects should provide the focus for the entire VV&A effort. When properly focused, the V&V effort is a critical risk-reduction tool, even in programs that are resource constrained.

How Does VV&A Impact the M&S Program Manager?

The primary effect of the VV&A effort on the M&S PM is risk mitigation. The ability to identify and mitigate risk is one hallmark of a successful M&S PM. There are many risks associated with developing and using a simulation, including the overriding risk that the simulation will produce inaccurate or noncredible results.

Risk is an inherent part of nearly every aspect of a simulation development program, including

- techniques used to develop adequate, accurate, and acceptable representations
- representations of phenomena, particularly highly complex phenomena, that either have no real-world counterparts or are not well understood (e.g., future weapon systems; aggregated representations of behavior)
- lack of, or perceived lack of, adequate resources (e.g., talent, time, money) to adequately address the M&S requirements
- unclear programmatic or representational objectives
- under-involvement of the User community in establishing the program's purpose and objectives

There are two basic types of risk associated with simulation development and use:

- **Development risks** -- risks related to the simulation development itself and typically relate to potential problems in meeting technical, schedule, or cost aspects of the simulation development or modification program. These are of primary concern to the M&S PM.
- **Operational risks** -- risks that arise from using the incorrect outputs of a simulation that are believed to be correct. These are of primary concern to the M&S User. Operational risks typically result from incorrect cause-and-effect relationships within representations. If operational risks are not mitigated, the simulation may return incorrect results and lack credibility as a tool for training or analysis.

⁵ See the special topic on Risk and its Impact on VV&A for additional information.

Development risk, the major concern of the M&S PM, is discussed in the sections below. Additional information on operational risk can be found in the core document on the User Role in the VV&A of New Simulations and the special topic on Risk and Its Impact on VV&A.

Development Risk

There are two main categories⁶ of development risk: **management** and **technical**.

Management Risk

Management risk involves problems associated with scheduling, resources, and requirements. Elements of the development process that have a high probability of impacting the level of management risk include

- **Requirements** --The state of the M&S requirements⁷ affects both management and technical risk. M&S requirements drive the simulation development process and serve as the basis for the project's technical development. Poorly defined requirements are a huge management and technical risk; one is never sure if the functionality being developed meets the requirements and rework is almost always required to meet an evolving requirements.

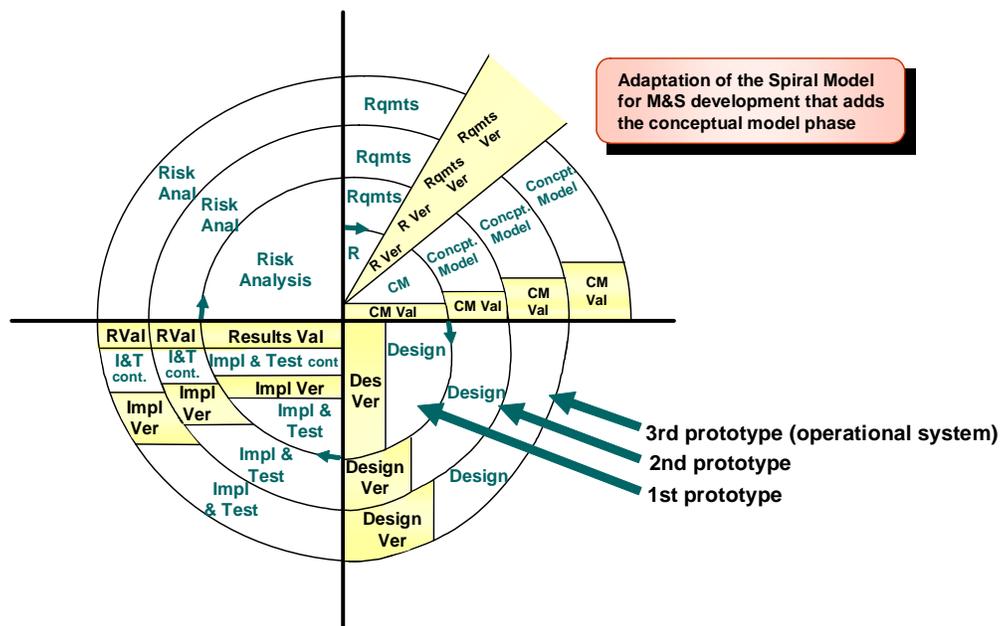
The more complex the representational requirements, the more critical V&V activities become. Requirements verification helps ensure that the project is working on the right representations and that the appropriate behaviors are developed to address the simulation objectives. Requirements traceability assessments help ensure that requirements are visible at every stage of the development process.

- **Development paradigm** -- The paradigm⁸ selected as the basis for development introduces different levels of management risk. For example, a spiral process (illustrated below) that builds off of previous iterations carries a level of inherited risk with each iteration. The V&V process can identify problems and mitigate risk within each spiral, thus reducing the level of inherited risk.

⁶ Some texts identify three categories: management, scheduling, and technical. For the purposes of the document, scheduling is considered one type of management risk.

⁷ See the special topic on Requirements for additional information.

⁸ See the special topic on Paradigms for M&S Development for additional information.



Spiral Process Paradigm

- **Resources** -- Limited time and money pose potential management risk if not carefully managed. The M&S PM's challenge in allocating resources is to decide where the resources will provide the greatest return on the investment. For example, more V&V resources may be deployed against the M&S requirements at greatest risk and less against those that are less critical to the success of the simulation.
- **Scheduling** -- Ample time should be built into the development schedule so problems identified by the V&V activities can be addressed in a timely manner and so resources (e.g., particular subject matter experts [SMEs], software, equipment) can be scheduled for competing purposes.

Management risks can be assessed by addressing the questions posed in the table below:

| Management Risk Issues |
|--|
| • Is there a set of clearly defined M&S requirements? |
| • Are the project's representational objectives well understood and accepted? |
| • Can a group of SMEs be identified to help develop approaches to represent the phenomena? |
| • Have sufficient recovery time and resources for addressing problems been built into the plan and schedule? |
| • Has a process been established to trace the M&S requirements? |

| Management Risk Issues |
|--|
| <ul style="list-style-type: none">• Are there sufficient resources (time, money, SMEs, equipment) to build the knowledge base? |
| <ul style="list-style-type: none">• Has a configuration management process been established to control the development effort? |

Technical Risk

Technical risk involves potential defects in the simulation's structure, code, data, interfaces, or a combination of these that can cause the simulation to fail to meet development requirements and thus fail to be useful for the specified application. Potential sources of technical risk include

- **Requirements** -- With clear M&S requirement statements, technical risk is generally lower. However, there are some representations that are high-risk by their very nature.

Example:

Human decision-making functionality in closed-form analytic simulations is difficult to represent because there is no "human-in-the-loop" (HITL). Human decision-making representations function on their own during execution of the simulation.

- **Data.** Data⁹ present some unique challenges that may become technical risks.
 - data that can completely meet the needs of the application are frequently difficult to find
 - data need well-documented pedigrees¹⁰ in terms of the authoritative data sources, quality assurance information, and sufficient metadata to provide confidence in the data quality¹¹ and fidelity
 - data can seldom be used in their original form, and the manipulation¹² done to aggregate, transform, or reduce data for use in a simulation raises questions regarding the quality and fidelity of the transformation

To instill confidence in the data and their preparation for use, data V&V¹³ should be conducted as part of (or in concert with) the V&V process. The M&S PM

⁹ See the reference document on M&S Data Concepts and Terms for additional information.

¹⁰ A well-documented pedigree includes information on the sources, characteristics, applications, and algebraic processes used in its preparation. Data verification should be conducted to ensure the fitness of each data selection.

¹¹ See the Data Quality Templates for additional information.

¹² The techniques (e.g., conversion, transformation, aggregation, de-aggregation) used to prepare the data for use in the current simulation should be carefully developed. Data verification and validation (V&V) should be conducted to ensure appropriateness of both the transformed data and the methods used for the transformation.

¹³ See the special topic on Data V&V for New Simulations for additional information.

should designate who is responsible for conducting the data V&V effort (e.g., the V&V Agent) and allocate appropriate resources.

- **Software Integration** -- Software integration presents some unique technical risks, particularly when a spiral development approach (discussed in the section on [Management Risk](#)), where numerous modules and components are under independent development, is used. Verification activities can help determine that the interactions and relationships represented, when integrated into a working system, are correct and sufficient to meet the simulation objectives. The V&V Agent can assist the M&S PM by reviewing and verifying the simulation domain standards as they are developed.

Although management risk and technical risk were discussed here independently, they are closely related. Management risk affects the degree of technical risk. Poor management practices can sabotage the best technical approach and result in a failed project. Management risk without sound practices in place can magnify the technical risk. Similarly, technical problems can cause delays that negatively impact the schedule and budget. Both are important and merit similar levels of attention. V&V activities can help mitigate risk in both by providing assessments of the correctness and completeness of the M&S requirements, assessments of the accuracy and appropriateness of the simulated representations, and indications of the likelihood of failure.

Identifying Risks

Risk assessment¹⁴ is a deliberate process for examining areas of uncertainty and identifying ways to increase the probability that simulation results will be correct. It involves three basic steps:

| Basic Steps in Risk Assessment |
|---|
| <ul style="list-style-type: none">• The User or designated representative categorizes the M&S requirements by defining a set of possible consequences that can occur if a requirement is not adequately met. |
| <ul style="list-style-type: none">• SMEs assign likely causes for each possible failure (e.g., algorithm complexity, data reliability, hardware-in-the-loop failure) to each requirement. These causes should be ordered by the difficulty of their detection. |
| <ul style="list-style-type: none">• The User and M&S PM assess the impact for each failure category and rank the requirements based on the likely impact of failure. |

This process results in an initial set of risks prioritized by their impact on the success of the simulation that can be used by the M&S PM in resource allocation and scheduling. Conducting a risk assessment early in the development process is crucial for effective decision-making and effective planning. However, it is equally important to reassess

¹⁴ See the special topic on Risk and Its impact on VV&A for additional information.

the risks at each phase of the development to ensure they continue to reflect the needs of the application.

Example:

The Software Engineering Institute's Software [Capability Maturity Model \(CMM\)](#)¹⁵ explicitly addresses risk management as a series of levels. Risks associated with cost, resources, schedule and technical issues can be identified, managed, and tracked through repeatable processes at Level II, and through a documented repeatable process for Level III. Specifically, the CMM recommends early identification of and action to deal with high-risk project objectives.

The CMM process is one mechanism that can help identify and mitigate high-risk development problems and assess the quality of the simulation.

The V&V effort is an important tool in eliminating failures, mitigating risk, and maintaining quality. Guided by timely, thorough, and repeated risk assessments, the V&V effort should focus on the issues shown in the table below.

| V&V Risk Mitigation |
|--|
| Assess the correctness and completeness of the representation |
| <ul style="list-style-type: none">• Are all essential components or features represented?• Is each traceable to an M&S requirement?• Does the Developer understand the required interactions and behaviors?• Are there SMEs on the military real-world functions who can assist? Are they available? Is their advice reflected in the conceptual model, design, and implementation?• Do the algorithms represent real-world interactions in a realistic and valid way? Are valid data available to populate the algorithm's variables? Are data generated to satisfy the measures associated with the functionality? |
| Assess the accuracy of the representation |
| <ul style="list-style-type: none">• Are the results consistent with real-world experience as compared to the conceptual model and SME opinion? |
| Assess the overall risk (i.e., likelihood of failure) |
| <ul style="list-style-type: none">• What is the chance that the representation will fail and the requirement will not be met? |
| Identify further mitigation measures |
| <ul style="list-style-type: none">• What reasonable and prudent measures can be taken to lower the overall risk that are consistent with the schedule, budget, and expert resources available? |

¹⁵ The Capability Maturity Model for Software (CMM or SW-CMM) is a model for judging the maturity of the software processes of an organization and for identifying the key practices that are required to increase the maturity of these processes. It is considered a de facto standard for assessing and improving software processes.

To accomplish most V&V tasks, there are a number of formal and informal V&V techniques¹⁶ that can be employed. What technique is selected and the intensity with which it is performed should depend on the importance of the M&S requirement being addressed and the degree of risk associated with its failure. The M&S PM's challenge in allocating resources is to decide where the resources will provide the greatest return on the investment. For example, more V&V resources may be allocated for the M&S requirements at greatest risk and fewer for those that are less critical to the success of the simulation.

What Are the M&S PM's Responsibilities in VV&A?

The M&S PM is responsible for allocating resources to the V&V Agent for V&V activities. The M&S PM should work to identify high-risk M&S requirements early so the V&V effort can be planned and appropriate resources allocated to focus on those areas. Additional V&V-related responsibilities of the M&S PM include:

- assist in the selection of appropriate V&V participants (i.e., V&V Agent, team members, SMEs) for the V&V effort
- ensure the V&V Agent is equipped with a full set of M&S requirements documents and has a correct vision of how the simulation should come together
- understand the acceptability criteria as defined by the User and Accreditation Agent and use them as a means of structuring and documenting the development effort
- establish exit criteria for each development phase and associated V&V activities
- ensure the V&V activities are properly integrated with development and test activities
- ensure the verification activities occur as part of a formal or semiformal review process and the results of each activity are documented
- provide adequate time in the schedule for V&V reviews and development responses
- ensure the V&V Agent is included in development and testing activities (e.g., M&S requirement reviews, code walks, operational testing [OT], developmental testing [DT])
- examine trade-off situations (e.g., mitigating risk and increasing credibility versus resource allocation, budget and scheduling constraints) continuously and recommend adjustments and changes to the User
- locate appropriate data to support V&V activities
- consider the V&V need for documentation (e.g., M&S requirements traceability) when determining appropriate development products and artifacts

¹⁶ See the reference document on V&V Techniques for additional information.

- consider the needs of the V&V effort when selecting tools¹⁷. (When possible, tools selected for development and testing should also support V&V activities¹⁸)

Example:

Computer Aided Software Engineering (CASE) tools selected for use in a development program should support requirements traceability and documentation through all phases of the development process; testing tools, whether purchased or built, should also be usable in V&V tasks to reduce costs and ensure consistency in the testing environment.

What Challenges Does the M&S PM Face Relative to VV&A?

The two primary V&V challenges for the M&S PM are achieving

- [Balance](#)
- [Integration](#)

Additional challenges include

- [Incomplete Requirements and Objectives](#)
- [Incomplete or Nonexistent Conceptual Model](#)
- [Formalized Development Products](#)
- [Rushed Transition from Design to Implementation](#)
- [SME Coordination and Resourcing](#)

Balance

The M&S PM should determine the proper balance of funding and allocation of resources between V&V activities and development to ensure the needs of the application are met. If the project is large and complex, the M&S PM may be encouraged to allocate additional resources (time, staff or budget) for development to meet the most difficult representational challenges. If the project is smaller, there may be a temptation to make some aspects of the simulation “better,” regardless of the needs of the application. In either case, allocation of additional resources for development can result in reduced resources for the V&V effort and lead to increased risks and reduced credibility for the simulation.

¹⁷ Additional tool selection considerations include: ability to crosswalk entities, processes, and interactions in the conceptual model to the design and implementation; visual feedback of design features; ability to provide results documentation in appropriate forms.

¹⁸ See the reference document on V&V Tools for additional information.

Integration

The integration of V&V and development activities is one mechanism that can help control both risk and cost. The M&S PM can help ensure proper integration by carefully scheduling phases and milestones to accommodate testing and reviews. If V&V activities are not conducted in concert with the appropriate development phases, their value is decreased because problems are identified too late to avoid impacting later development phases, increasing the cost of their correction.

Incomplete Requirements and Objectives

In order to establish appropriate development and V&V priorities, the M&S PM needs

- clearly stated, consistent, completely defined, verified M&S requirements
- sufficient information to understand the level of development risk that can result from incomplete understanding of the requirements
- sufficient information to understand the level of credibility the User requires

The M&S PM should work with the User to produce unambiguous and specific requirements early so they can be verified and associated risks ascertained in time to be incorporated in initial plans and schedules. Because requirements definition and refinement is often an ongoing process continuing through the early stages of development, the M&S PM should ensure that plans and schedules are modified as needed to address the requirements. If necessary, the M&S PM should work with the User to establish a requirements oversight group to define and monitor requirements as they are incorporated into the simulation.

Incomplete or Nonexistent Conceptual Model

The conceptual model¹⁹ provides the bridge between the User-defined requirements and objectives and the simulation design, showing the Developer's concept of what needs to be built. Building a conceptual model involves time and resources to identify and document the real-world entities, processes, tasks, interactions, and behaviors that should be represented in the simulation. Validation of the conceptual model, when done in a timely manner, can identify problems (e.g., misinterpretation of requirements, incorrect level of fidelity, inconsistent representations) before resources have been expended on design or development. The M&S PM should allocate sufficient resources for both building and validating the conceptual model.

When a conceptual model is not produced as a specific product or when the conceptual model is incomplete, M&S requirements may be misinterpreted or overlooked in the implementation. This may result in costly revisions, scheduling delays, or even failure to accredit. When a formal conceptual model does not exist, the information can be

¹⁹ See the special topic on Conceptual Model Development and Validation for additional information.

pieced together by examining different development artifacts (e.g., requirements documents, simulation specifications, design products); however, the necessary information may not be readily or credibly identified as such.

Example:

Because the JWARS program did not have a detailed conceptual model specification, the V&V Agent was required to gather multiple artifacts and deliverables and piece together the elements of a conceptual model. The individual elements of this “surrogate” conceptual model were then validated (individually and together) to assess the issues normally addressed by conceptual model validation.

Without a clearly defined conceptual model, the V&V Agent may have to expend additional time, effort, and resources to obtain the evidence needed for accreditation. Without a validated conceptual model, the Developer’s concept may not be articulated until a later phase of the development process. There is no traceability between the requirements and the code, no identification of inconsistencies between requirements, and no referent²⁰ that will serve to bound the validation process. Then the Developer may need to spend additional time, effort, and resources reworking the simulation design and/or implementation. To ensure development of a complete, validated conceptual model, the M&S PM should ensure that it is a deliverable in the contractual agreement with the Developer.

Formalized Development Products

Traditional simulation development begins with the definition of the User’s requirements and objectives and proceeds with the development of a concept illustrating how the Developer intends to meet the requirements; the creation of a design showing how this concept should be implemented in code; and the development of the subsequent code. It is important to have formal products that map to each of these development phases:

- requirement definitions
- conceptual model
- designs (both preliminary and detailed)
- documented code

See the section on [Documentation Requirements](#) [p. 38] for additional information regarding formalized development products.

Rushed Transition from Design to Implementation

²⁰ Referent -- a codified body of knowledge about a thing being simulated. Additional information is available in the special topic on Validation.

There is a natural tendency for the M&S PM, User, and Developer to want to rush into implementation; however, the M&S PM should budget sufficient time during the design phase for verification activities to be conducted and problems, particularly those in high-risk areas, to be resolved before time and resources have been expended developing code.

SME Coordination and Resourcing

Subject matter experts (SMEs)²¹ are an especially important resource for both the M&S development and the VV&A processes (e.g., the User involves SMEs during requirements definition; the Developer uses SMEs in conceptual model development; the V&V Agent relies on SMEs during many validation activities; the Accreditation Agent normally includes SMEs in the accreditation assessment). As the manager of resources and schedules, the M&S PM should serve as the coordinator of SME activities to ensure their involvement is scheduled at appropriate times and adequate resources and time are available for their participation.

At a minimum, SME costs would consist of travel expenses. However, because of the increasing scarcity of SMEs,²² it is becoming more common for SMEs to require payment for their time as well. To minimize SME costs, alternatives to frequent mass meetings should be considered (e.g., holding teleconferences and web-based meetings; sharing information and conducting reviews through e-mail). Careful planning and scheduling of SME meetings and the preparation and advanced distribution of read-ahead packages can also ensure efficient use of SME time.

Role of the M&S PM in the Overall Problem Solving Process

Problem Solving Process

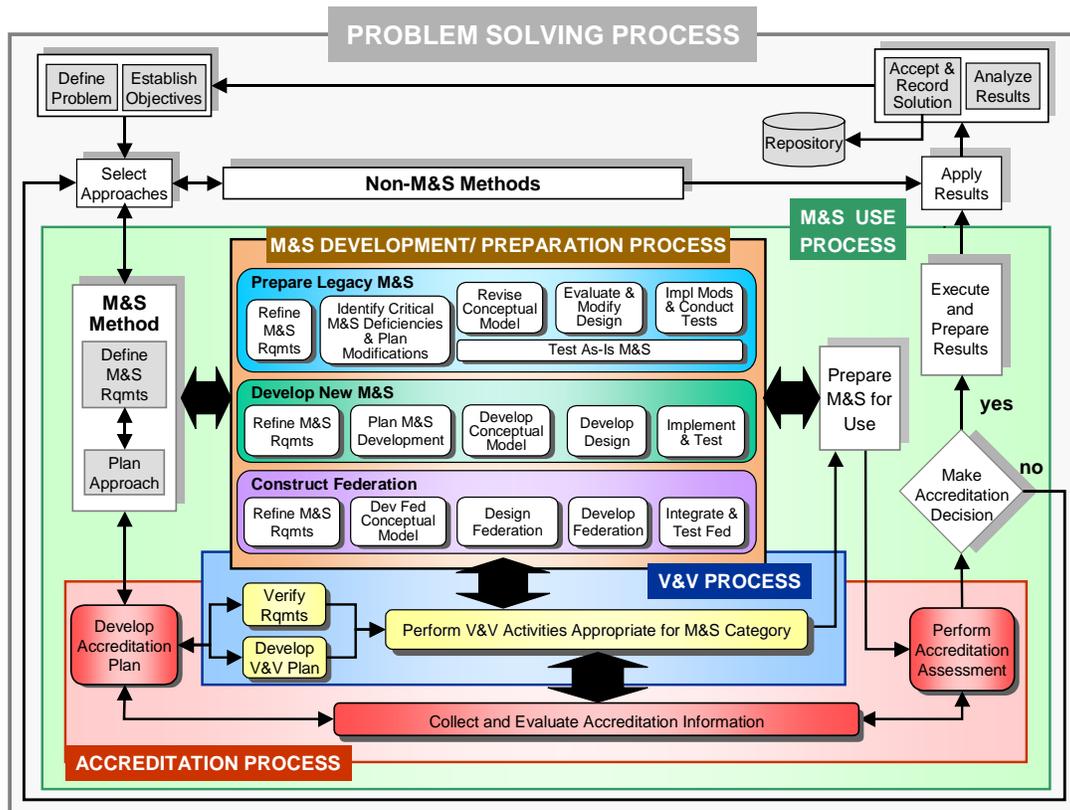
The [Problem Solving Process diagram](#) below shows how the M&S life cycle fits into the overall problem solving process. The diagram depicts the relationships between the ***Problem Solving Process, M&S Use Process, M&S Development Process, V&V Process, and Accreditation Process*** as a series of nested boxes. Each nested process contains a series of individual boxes that represent the basic individual activities and functions considered essential to complete that process.

The overall problem solving process is the province of the User. The User initiates the entire process by first defining the problem and establishing the objectives and then by

²¹ See the special topic on Subject Matter Experts and VV&A for additional information.

²² Beginning in the early 1990s with the downsizing of the military and government agencies, the number of people to attain appropriate levels of expertise diminished while the demand for their expertise increased. Whereas the majority of the SMEs either once resided in the military or were employed by the government, now many now reside in the private sector and require remuneration for their participation.

selecting the method or methods (e.g., modeling and simulation, experimentation, statistical analysis, live testing) to resolve it. The User culminates the process by applying the methods (e.g., making the decision to accredit the simulation for use, running the simulation, accepting the simulation results) and analyzing, accepting, and recording the overall solution.

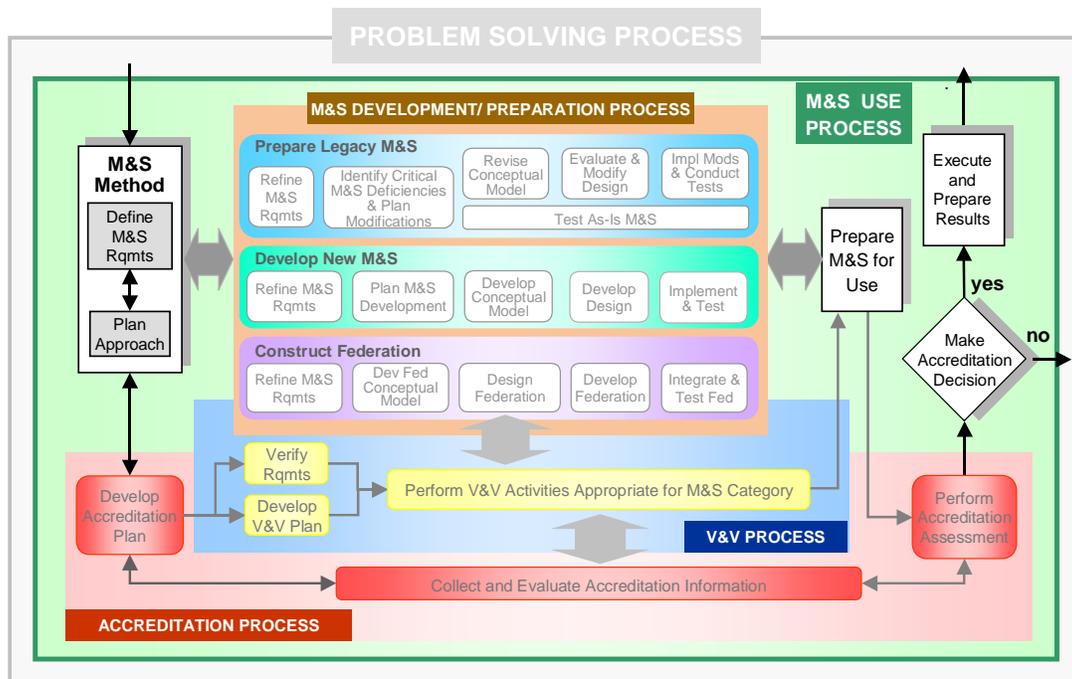


The Overall Problem Solving Process

M&S Use Process

Once M&S has been selected as the method to use, the first nested process in the **Problem Solving Process**, the **M&S Use Process** (shown below), begins. At the beginning of this process, during the **M&S Methods** phase, M&S program management is initiated and an M&S PM²³ is designated to oversee issues relating to cost, scheduling, resourcing, etc.

²³ The designation of an M&S PM depends in part on the size and scope of the simulation program. When the simulation to be developed is relatively small and straightforward, M&S PM responsibilities may be handled by the Developer or the User.



M&S Use Process in the Problem Solving Process

Two basic activities are performed during this phase, **Define M&S Requirements** and **Plan Approach**. During these activities, the M&S PM joins the User in performing a number of tasks that affect the V&V effort. These are listed below and discussed in the following sections.

- Define M&S Requirements
 - [Understanding the Problem](#)
 - [Defining M&S Requirements, Metrics, and Acceptability Criteria](#)
- Plan Approach
 - [Assessing Risk](#)
 - [Establishing Contractual Agreements](#)

Define M&S Requirements

Understanding the Problem

A well-formulated problem is essential to the credibility and the ultimate accreditation of a simulation. An ill-defined problem can be one of the major factors contributing to increases in the costs and risks associated with the M&S development. Even before the decision is made to use simulation to help resolve a given problem, the problem domain must be established. The problem should be defined and articulated clearly

enough that the User, and later the M&S PM and Developer, can see how simulation can help solve it. Issues to be addressed are shown in the table below.

| Problem Domain Questions |
|--|
| <ul style="list-style-type: none"> • What is the basic problem to be solved? What are the objectives? What questions need to be answered? |
| <ul style="list-style-type: none"> • What particular aspects of the problem will M&S be used to help solve? |
| <ul style="list-style-type: none"> • What is the scope of the problem? What boundaries or mission space apply? |
| <ul style="list-style-type: none"> • What decisions will be made based on the simulation results? |
| <ul style="list-style-type: none"> • What are the risks that might result from acceptance of erroneous simulation outputs or decisions based on them? |

An analysis of the problem can help ensure the right problem is being addressed and the objectives of the problem are clearly understood. In addition, the results of this analysis can be used to help define M&S requirements, establish priorities, allocate resources, and serve as a foundation for the development program. A formal problem analysis is normally conducted by the User with participation from the M&S PM, and others (i.e., SMEs, Accreditation Agent, Developer, and V&V Agent when available). The initial problem analysis need not be highly detailed to provide the M&S PM with sufficient information to assist in the allocation of resources and scheduling. As the development proceeds, the priorities identified should be reexamined and adjusted to accommodate any changes in objectives or requirements.

Defining M&S Requirements, Metrics, and Acceptability Criteria

Once the problem is understood, the M&S requirements²⁴ and their associated metrics and acceptability criteria are defined by the User with participation from the M&S PM and others (i.e., SMEs, Accreditation Agent, Developer, and V&V Agent when available). The questions listed below help determine what information is needed from the simulation and how accurate that information should be to address the needs of the application.

| M&S Requirement Questions |
|--|
| <ul style="list-style-type: none"> • What information is needed to support the key problem decisions or to resolve the key problem issues? |
| <ul style="list-style-type: none"> • What specific simulation outputs relate to the information required? |
| <ul style="list-style-type: none"> • How good do these outputs need to be, i.e., what is the level of tolerance for uncertainty in the results? |
| <ul style="list-style-type: none"> • How will simulation output be used to produce the information needed to achieve the problem objectives, resolve the issues, and/or make the necessary decisions? |

Plan Approach

²⁴ See the special topic on Requirements for additional information.

Assessing Risk

One of the most critical functions impacting V&V planning is the assessment of risks. A risk assessment, as discussed in [Identifying Risks](#) [p. 6], should be conducted as early as possible after the requirements have been drafted and risk mitigation measures should be initiated as soon as the initial assessment results are known. The M&S PM's responsibilities during risk assessment are shown in the table below.

| The M&S PM's Role in Risk Assessment |
|---|
| • Identify SMEs |
| • Solicit information and assistance from similar successful development efforts |
| • Select the Developer and V&V Agent in time to participate in the mitigation and, if possible, the risk assessment process |
| • Evaluate the development paradigm to determine if it is sufficient |
| • Explore options in the development process ²⁵ to accommodate high-risk areas |
| • Adjust resource allocations and timelines to ensure high-risk areas receive appropriate attention |
| • Schedule risk assessment reviews at appropriate times throughout the development process |
| • Assess data risks by reviewing the availability of authoritative data |

Risks should be reassessed throughout the development process as problems arise, adjustments are made, and new information becomes available. The M&S PM should oversee any changes and make adjustments when needed to ensure the development remains focused on the priorities.

Establishing Contractual Agreements

The M&S PM is responsible for designating both the Developer and V&V Agent and overseeing all contractual agreements relating to the development program. The M&S PM should ensure the contractual statements of work (SOWs) involve only tasks and products that are necessary and sufficient to support program needs such as those shown in the table below. All understandings and agreements should be formalized. As plans evolve, any modifications affecting a contractual agreement should also be formally incorporated.

| Typical SOW Information |
|--------------------------------|
|--------------------------------|

²⁵ If there are several high-risk aspects in the development, consider employing a rapid prototype paradigm to produce an early deliverable. The prototype period can be used to explore alternative methods for approaching the high-risk areas and the representations can be embedded in an environment that resembles the objective simulation. The development paradigm and scheduling can be examined for feasibility. Implicit requirements may be discovered that should be addressed during development.

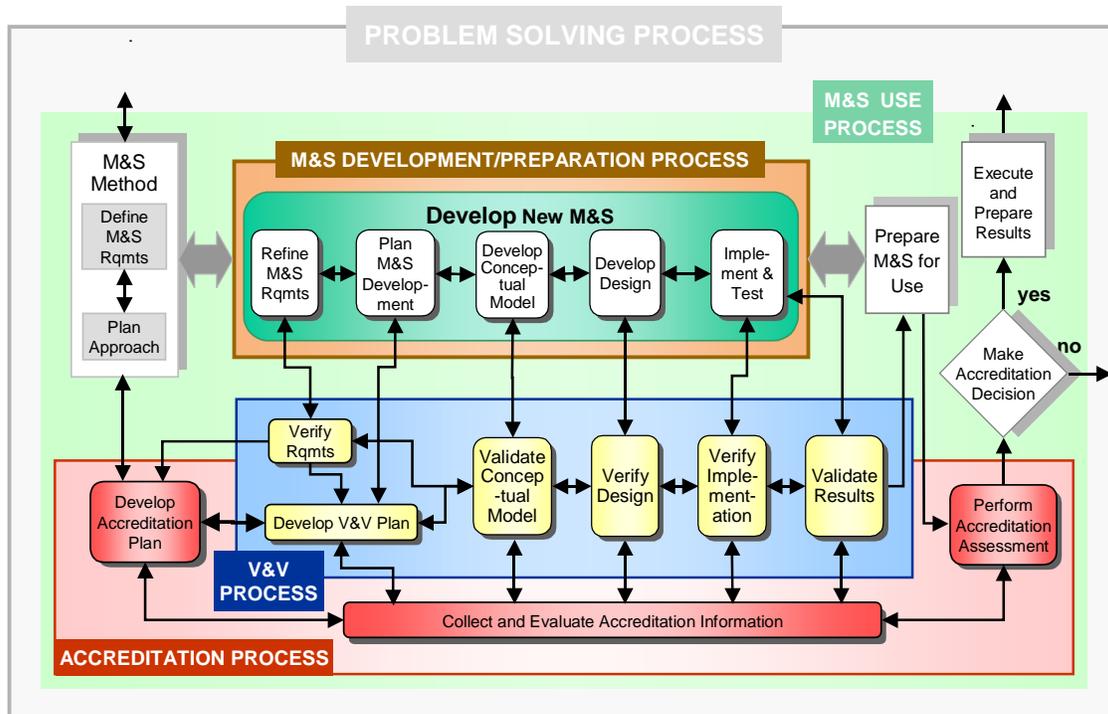
| Typical SOW Information | |
|-------------------------|--|
| • Problem statement | objectives to be accomplished by the SOW |
| • References | sources of requirements and top-level development objectives |
| • M&S requirements | collection of requirements that a simulation must meet to serve a particular purpose |
| • Tasks | general approach to accomplish objectives |
| • Products | products and artifacts to be produced |
| • Milestones | time period for delivering products |

This information provided should be understandable with minimum inference. Questions should be resolved immediately and contracts modified to clarify issues. All products and artifacts identified should include all those needed during subsequent phases of development, those needed for testing and the V&V effort (e.g., the conceptual model), and those needed for configuration management. Form and/or format specifications should be included. Milestones should be scheduled to allow time for feedback from associated V&V activities and development responses.

M&S Development/Preparation Process

The ***M&S Development/Preparation Process for New Simulations*** begins when the M&S PM designates the Developer. The M&S PM and Developer proceed to define the [development profile](#) [p. 21], select the [development paradigm](#) [p. 3], establish the development schedule, and initiate the plan. The M&S PM should then oversee all aspects of simulation development.

Regardless of which development paradigm is followed, the development process for new simulations, ***Develop New M&S***, consists of the six basic phases: **Refine M&S Requirements, Plan M&S Development, Develop Conceptual Model, Develop Design, Implement and Test, and Prepare M&S for Use**. As illustrated in the following figure, associated with each phase of the development is a corresponding V&V activity that examines and tests the progress in that phase, provides timely feedback, and collects evidence of the simulation's capabilities to be used in the accreditation assessment. Each activity consists of a number of tasks in which the M&S PM can participate. The M&S PM's role in these development and V&V activities and the associated accreditation process is discussed in the following section.



M&S Development/Preparation Process for New M&S

VV&A Functions of the M&S PM Role in New M&S Development

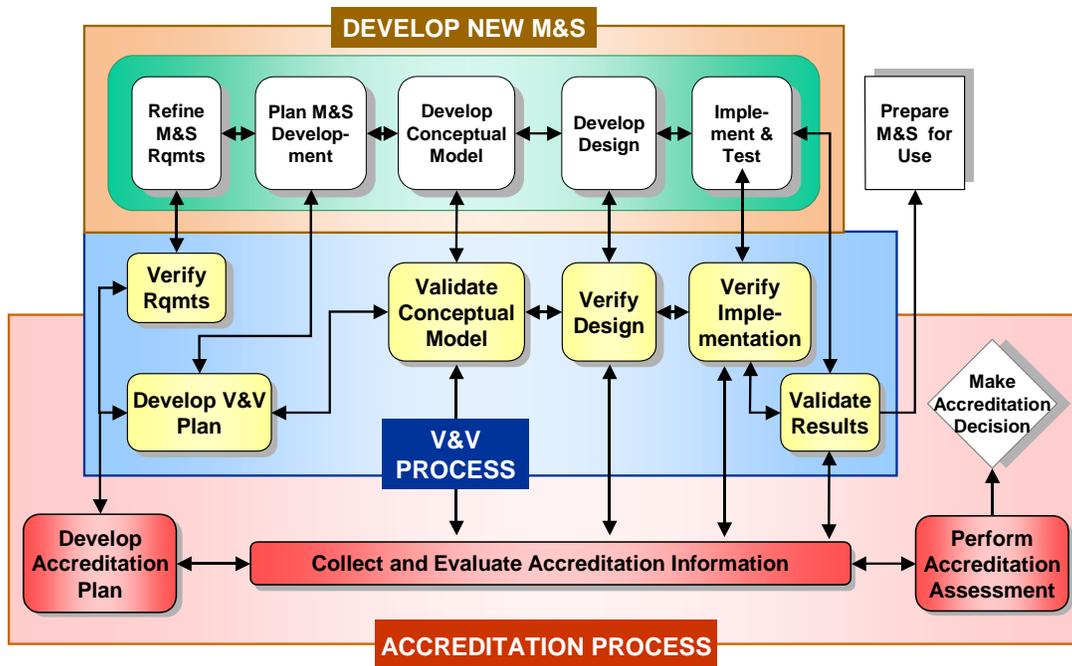
Although the M&S PM can be an effective participant in the VV&A effort, the M&S PM role, as illustrated in the roles and responsibilities diagram,²⁶ is primarily one of oversight and resource allocation for both planning the V&V effort and implementing the V&V plan. In addition, throughout the development process, the M&S PM has a number of responsibilities that particularly impact the V&V effort.

The new M&S development process, **Develop New M&S**, consists of six basic phases. Associated with each phase is a corresponding V&V activity, as shown in the diagram below. These phases and activities are listed below and discussed in the following paragraphs.

- [Refine M&S Requirements Phase](#)
- [Plan M&S Development Phase](#)
- [Develop Conceptual Model Phase](#)
- [Develop Design Phase](#)

²⁶ See the diagram, *Typical Roles and Their Responsibilities* and the section on “Roles and Responsibilities” in the *Key Concepts* document for additional information.

- [Implement and Test Phase](#)
- [Prepare for Use Phase](#)



VV&A in New M&S Development

Refine M&S Requirements Phase

Refine M&S Requirements

The early phases of a development are perhaps the most critical for successfully meeting the program's objectives and establishing a tailored and supportive V&V process. During this phase, the M&S PM works with the Developer and User to define the simulation domain requirements and participates in the analysis of all M&S requirements²⁷ to determine if additional clarification, enhancement, or decomposition are needed.

The following table identifies major items of concern to the M&S PM during this phase:

| Major Concerns During M&S Requirements Refinement |
|---|
| Problem, user, and simulation domains should be addressed in the M&S requirements |

²⁷ See the special topic on Requirements for additional information.

| Major Concerns During M&S Requirements Refinement |
|--|
| <ul style="list-style-type: none">Frequently, requirements development processes focus on the problem domain, leaving the user and simulation domain requirements definition up to the Developer. This approach usually results in less-than-satisfactory outcomes. |
| Requirements should be measurable |
| <ul style="list-style-type: none">Measures (e.g., measures of performance [MOPs], measures of effectiveness [MOEs])²⁸ that derive logically from generalized M&S requirements statements are usually the best approach to building adequate and accurate requirements. |
| M&S requirements should be traceable |
| <ul style="list-style-type: none">Each requirement and its component parts (e.g., metrics, definition) should be traceable to an objective. |
| Requirements databases should support traceability throughout the development process |
| <ul style="list-style-type: none">Records should be unique so that as the conceptual model, design, and implementation phases proceed, the Developer can demonstrate and the V&V Agent can verify the need for each product through reference to the requirement. |
| Acceptability criteria should be developed to describe how the simulation should perform when completed |
| <ul style="list-style-type: none">The effort should be led by the Accreditation Agent with participation from the User, M&S PM, Developer, V&V Agent, and designated SMEs.Acceptability criteria should be fully developed during the conceptual modeling phase and continually reviewed throughout the development process to ensure they remain appropriate and sufficient. |
| Required data should be explicitly identified and the search for authoritative sources of data begun immediately |
| <ul style="list-style-type: none">Obtaining data that fit the needs of the application and simulation is frequently high risk.Data acquisition and validation activities should begin as soon as potential data sources are identified based on an assessment of the types of data needed.Additional data analysis should be done when the algorithms using the data have been developed, when the data have been acquired, and when the data have been prepared for use in the simulation.²⁹ |

Verify M&S Requirements

M&S requirements verification addresses many of the concerns listed in the preceding [table](#) including the completeness, measurability, consistency, and traceability of the M&S requirements. The M&S PM's role in requirements verification includes

- providing information about the programmatics of the development process
- ensuring the creation and maintenance of a requirements tracing database to hold

²⁸ See the special topic on Measures for additional information.

²⁹ See the special topic on Data V&V for New Simulations for additional information.

- source documents containing the originating user and problem domain requirements
- simulation domain requirements
- derived requirements and their sources
- acceptability criteria for each requirement
- pointers from the requirements to the appropriate locations in the software design where requirements are addressed
- pointers from the requirements to appropriate software modules
- pointers from the requirements to appropriate test procedures and reports
- providing the V&V Agent access to all requirements documentation
- maintaining configuration control of the requirements database(s)
- developing a cross-walk between acceptability criteria and requirements that shows how each requirement is addressed by its associated acceptability criteria

Plan M&S Development Phase

Plan M&S Development

The major responsibilities of the M&S PM that impact the V&V effort during the planning phase include [profiling the development effort](#), [defining the development environment](#), [identifying critical development elements and issues](#), and helping [develop the V&V plan](#).

Profiling the Development Effort

A development profile identifies what the simulation is supposed to do and how it is supposed to be used. It should be used during V&V planning to develop an appropriate V&V approach. It can be constructed by the M&S PM, with support from the Developer and User, by collecting and organizing essential planning information such as is shown in the table below.

| Simulation Profiling Information |
|---|
| • Specifications on the system(s) and phenomena being modeled |
| • Information about the roles, missions, and operational objectives |
| • Overall schedule for planned use -- simulation development, V&V, and accreditation should be completed before this date |
| • Environment, geography, terrain, ocean, space, etc. |
| • Scenario-driven or general operational capabilities lists |
| • Resourcing agreements and participant identification |
| • Deployment site or sites for the simulation |
| • Uncertainties and risks |

| Simulation Profiling Information |
|---|
| <ul style="list-style-type: none">• Miscellaneous planning information (these are specific to the use case and the expected amount of simulation preparation involved) |
| <ul style="list-style-type: none">• Identification of SMEs who will assist in developing the representations and algorithms needed to model behaviors and interactions and a plan for scheduling and allocating SME resources |
| <ul style="list-style-type: none">• Identification of User personnel who developed and/or validated the M&S requirements |

Defining the Development Environment

The development environment describes how the simulation is going to be built. The M&S PM and the Developer should make preliminary decisions regarding development factors, such as those listed in the table below.

| Development Environment Information |
|---|
| <ul style="list-style-type: none">• Development paradigm |
| <ul style="list-style-type: none">• Implementation approach (object-oriented or procedural) |
| <ul style="list-style-type: none">• Simulation development language |
| <ul style="list-style-type: none">• Hardware and platform requirements |
| <ul style="list-style-type: none">• Development and testing tools |
| <ul style="list-style-type: none">• Development products |

The M&S PM should ensure that the tools selected for development and testing support V&V activities whenever possible and that the products produced during development and testing contain the information necessary to support the V&V effort.

Identifying Critical Development Elements and Issues

The critical elements of the development process lay the foundation for identifying necessary V&V activities. Typical development elements and issues are identified in [Appendix A](#). Additional development issues should be added based on the results of the risk analysis.

Develop V&V Plan

The major planning functions of the M&S PM that affect V&V are listed below and discussed in the following paragraphs.

- [Scoping the V&V Effort](#)
- [Identifying Critical V&V Issues](#)
- [Developing the V&V Schedule](#)
- [Tailoring and Leveraging the V&V Effort](#)

- [Reviewing the V&V Plan](#)

Scoping the V&V Effort

The V&V plan should be developed by the V&V Agent in cooperation with the M&S PM, User, Developer, and Accreditation Agent all of whom bring essential information to the planning process. The V&V planning effort begins by reviewing information about the problem and the development effort to determine the magnitude of the overall V&V effort.

| Information Used in Scoping the V&V Effort |
|--|
| • Results of the problem analysis |
| • M&S requirements ³⁰ and their associated acceptability criteria |
| • Results of risk assessment -- priorities |
| • Development profile [p. 21] |
| • Development environment [p.22] |
| • Development plans and schedules |

In addition to providing information to determine the scope of the V&V effort, the M&S PM also assists by identifying V&V participants (e.g., V&V Agent, V&V team members,³¹ SMEs), and allocating resources.

Identifying Critical V&V Issues

The critical development elements (see [Appendix A](#)) identified by the M&S PM and Developer are used to identify critical V&V issues (see [Appendix B](#)), which, in turn, are used to determine appropriate V&V activities.

Developing the V&V Schedule

The results of the risk assessment should identify areas where both V&V resources and time should be concentrated. V&V tasks should be scheduled to coordinate with the development activities and to allow sufficient time in both schedules for problems to be identified and resolved quickly.

Initial V&V scheduling should consist of a simple, straightforward process of mapping appropriate V&V tasks and times to each development phase. However, when unexpected changes occur, such as the addition of new M&S requirements, the nonavailability of desired data, or the discovery of problems that result in development delays, the V&V schedule and plans have to be modified.

³⁰ See the special topic on Requirements for additional information.

³¹ The size and composition of a V&V team should depend on the nature of the current problem (i.e., problem and user domains involved), the size and complexity of the simulation being developed, and the results of the risk assessment, which provide an indication of where V&V activities should be focused.

The V&V schedule should be developed by the V&V Agent in cooperation with the M&S PM and Developer. The primary responsibility of the M&S PM is to oversee the scheduling (see [Appendix C](#)) to ensure that both the development and V&V efforts assign reasonable timelines and assist with any rescheduling when necessary. In addition, the M&S PM should

- integrate specific V&V tasks throughout the development process
- determine exit criteria for each development phase and associated V&V activities

Tailoring and Leveraging the V&V Effort

Tailoring is the careful selection of V&V tasks to address the needs of the application. It is done to ensure efficient use of resources. The V&V effort is tailored by focusing on the areas of highest risk (see table below); identifying the activities and tasks that can best provide the evidence to mitigate those risks; and scheduling the tasks to correspond to specific development activities. The M&S PM should ensure that sufficient resources are allocated to perform the necessary tasks.

- **High-risk areas** -- As discussed in Risk Assessment,³² the User, M&S PM, Developer, V&V Agent, and Accreditation Agent should conduct a risk assessment to determine the areas of greatest risk to the credibility of the simulation. Examples of potential high-risk areas are shown in the table below.

| Potential High-Risk Areas |
|---|
| Representations that contain significant technical risk |
| <ul style="list-style-type: none">• experimental weapon systems; new hardware configurations |
| Suitable battle environments (land, air, space, and sea) and interactions |
| <ul style="list-style-type: none">• showing damage (e.g., craters caused by explosions); having damage impact entity behaviors (e.g., tanks driving over building rubble) |
| Representations that involve management risk |
| <ul style="list-style-type: none">• achieving consensus regarding appropriate representations, behaviors, and data (e.g., Joint applications) |
| Simulation domain risks; time management issues; causality problems |
| <ul style="list-style-type: none">• event management; integration of large, complex simulations |

The V&V effort should determine aspects of these areas that can be verified or validated and identify appropriate tasks to perform for each.

Example:

³² See the special topic on Risk and Its Impact on VV&A.

To validate an experimental weapon system for which real-world data do not exist, the V&V effort would need to establish a referent to be used to support test and validation activities. The V&V Agent should work with the testing team to establish scenarios³³ and with the User and M&S PM to identify appropriate SMEs to define the validation data.

- **Budgetary considerations** -- Tailoring also involves achieving balance between the simulation credibility and risk reduction objectives and real-world constraints driven by the schedule, availability of resources, and budget. Having the resources and budget allocated before the User and M&S PM have sufficient knowledge of the challenges of the development is a major concern. The M&S PM should make sure that adequate problem analysis and risk assessment are done before decisions are made regarding resource allocation and funding.

During the initial tailoring process, the V&V Agent should conduct a preliminary cost estimation independent of preconceived notions of the budget to establish a cost estimate for the V&V effort. This estimate can be compared to the allocated budget to determine what trade-offs are justified or used to persuade the M&S PM to increase the V&V budget. When the estimated cost and allocated budget are very close, adjustments may be fairly easy to make either in the V&V plans, by the V&V Agent, or in the allocation of funds by the M&S PM. However, if the budget is well below the estimated cost, then the M&S PM should work with the V&V Agent and User to determine appropriate trade-offs between funding and the decreased credibility and increased risk that can result from an inadequate V&V effort.

Leveraging, using the results of work performed by the Developer or during developmental and operational Test and Evaluation (T&E)³⁴ efforts to satisfy the V&V requirements, is one method to reduce costs without sacrificing V&V effectiveness. For example, if the Developer performs code verification as part of the development process and it addresses the necessary V&V issues, the V&V Agent should be able to share the evidence and reuse the results without repeating the process.

Leveraging is possible when both V&V tasks and development or test objectives are based on the acceptability criteria and the test scenarios involved can satisfy both needs (i.e., resulting data are usable by both). When activities are leveraged, the V&V Agent should be able to participate in the tests or use tests results to address V&V issues. When using the results, the V&V Agent has an obligation to review the information and determine its adequacy before accepting it. Such a review typically requires less than 10 percent of the time and resources that would be expended in

³³ Whenever possible, the same scenarios should be used for validation and testing. This practice increases the consistency of the results and reduces duplication of effort. Test scenarios should always be constrained by the needs of the application (i.e., a simulation should not be tested using a desert scenario if the application is investigating ice floes in Antarctica).

³⁴ See the reference document on T&E and VV&A Integration for additional information.

separate testing. The M&S PM should review development, testing, and V&V activities to ensure leveraging opportunities are exploited and duplicate efforts are avoided.

Reviewing the V&V Plan

The V&V plan should be reviewed by the User, M&S PM, Developer, and Accreditation Agent to ensure it addresses each of their concerns:

- **User** -- to ensure the V&V plan focuses on high-risk areas and covers the application needs sufficiently
- **M&S PM** -- to ensure the V&V plan involves a realistic timeline and does not exceed the allocated resources
- **Developer** -- to ensure the V&V effort can provide feedback about development issues in a timely fashion
- **Accreditation Agent** -- to ensure the V&V tasks included are necessary and sufficient for addressing the accreditation needs

V&V planning should not become a contest to provide either the absolute lowest cost effort or the most elaborate procedures and analyses. The V&V plan should detail the best-value balance between program needs and real-world constraints. The V&V plan should be considered an iterative document. It should remain flexible in order to adjust to changes throughout the development process.

Develop Conceptual Model Phase

Develop Conceptual Model

While conceptualization occurs in every development effort, in some development programs the M&S PM allocates resources (including funding for SMEs) to the Developer to conduct knowledge acquisition and develop a conceptual model.³⁵ The conceptual model is the bridge between the requirements and the code. It describes the domains of interest and assumptions upon which the simulation will be built and includes all the important features of the simulation (e.g., objects, elements, scenarios, representations, behaviors, functions, data, fidelity). When formally developed, it serves as a blueprint by which the M&S PM, User, Developer, and others can understand precisely what needs to be built.

The conceptual model can take on different forms as a result of the development paradigm selected, resource and time constraints of the program, and the background and experience of those involved. Regardless of what form the conceptual model takes, the M&S PM should provide the resources to ensure that the information contained in it is sufficient to support follow-on development phases and VV&A activities.

³⁵ See the special topic on Conceptual Model Development and Validation for additional information.

Validate Conceptual Model

Conceptual model validation involves

- assessing the degree to which the conceptual model accurately describes the real-world entities and processes, behaviors, entity attributes, and cause-and-effect relationships to be represented in the simulation
- ensuring all the M&S requirements have been addressed accurately and completely
- ensuring each element is defined at a level of fidelity that is appropriate for the application

The validated conceptual model not only serves as the foundation for the simulation design but also becomes the referent, the basis for results validation.³⁶ The M&S PM should allocate resources to the V&V Agent to conduct conceptual model validation and should ensure appropriate SMEs are available to support both conceptual modeling and validation.

The M&S PM contributes to conceptual model validation by

- developing a detailed specification describing the conceptual model format and content
- ensuring that a conceptual model is developed and documented according to the prescribed specification
- making conceptual model artifacts available to the V&V Agent
- identifying all data sources for the V&V Agent

Based on results of the conceptual model validation, the M&S PM also assesses where changes need to be made. If changes are needed because of errors in the conceptual model, the M&S PM works with the Developer to determine the changes needed. If changes are needed because of inconsistencies or ambiguities in the requirements, the M&S PM works with the User to resolve the problems. Once a new course of action has been determined, the M&S PM adjusts schedules, plans, and resource allocations accordingly.

Develop Design Phase

Develop Design

³⁶ For more information on referents, see the special topics on Validation and on Conceptual Model Development and Validation.

During the design phase, the capabilities derived from the requirements, architectural representations, algorithms, behaviors, interactions, data needs, constraints, and limitations defined and described in the validated conceptual model are translated into a design specification that will support their implementation in software and hardware. Design development is an iterative process, producing first a very basic, high-level design and ending with a completely specified detailed design. The design process is affected by both the development paradigm selected to shape the design process and the programming method to be used (traditional process-oriented or object-oriented). Together these determine when specific information is available, what levels of maturity different products attain, and how and when resources will be used. During this phase, the M&S PM monitors the translation of the conceptual model into design specifications, the selection of data to be used in the simulation, and all testing and V&V activities.

Verify Design

Design verification activities are conducted to determine the degree to which the design corresponds to the conceptual model³⁷ and to assess the appropriateness of the data selections. The M&S PM monitors the V&V tasks involved (see the core document on V&V Agent Role in VV&A of New Simulations and the special topic on Data V&V in New Simulations for information on specific tasks) and leads an effort to coordinate testing and V&V tasks. The generation of the development test plans is the responsibility of the Developer. During the design phase, development test plans are typically available for review and assessment by the V&V Agent. The M&S PM should encourage the V&V Agent and Developer to coordinate their testing needs to reduce excessive and repetitive testing. Leveraging testing and V&V efforts can save time and resources and is usually more cost-effective than attempting to prepare and run independent validation tests, although this is a possible alternative.

The M&S PM's role in design verification includes

- maintaining the requirements tracing database that traces each requirement through to the design artifacts
- identifying the sources for each input data element
- maintaining instance databases, data descriptions, and metadata that describe the intended use of the data within the simulation³⁸
- making all design artifacts available to the V&V Agent
- making all test plans available to the V&V Agent

Based on results of the design verification effort, the M&S PM also assesses where changes need to be made. If changes are needed because of errors in either the

³⁷ This does not mean that the design has to “look” like the conceptual model, but that all aspects of the conceptual model have to be accounted for in the design.

³⁸ See the reference document on M&S Data Concepts and Terms for additional information.

design or data, the M&S PM works with the Developer to determine the changes needed. If changes are needed because of inconsistencies or ambiguities in the requirements, the M&S PM works with the User to resolve the problems. Once a new course of action has been determined, the M&S PM adjusts schedules, plans, and resource allocations accordingly.

Implement and Test Phase

Implement and Test

During the implementation and testing phase, the M&S design is realized in hardware and software. Both types of components are constructed, tested, and integrated, and the actual data and databases are installed and tested. Two basic types of testing are normally involved during this phase of simulation development:

- Developmental Testing (DT) and Developmental Testing and Evaluation (DT&E) are a Developer responsibility and should be conducted by the Developer based on a simulation DT or DT&E plan.
- Operational Testing (OT) and Operational Test and Evaluation (OT&E) are normally an external function that is the responsibility of the Operational Test Authority (OTA). The OTA is either established by organizational policy, appointed by the M&S PM, or selected by the User. OT&E is normally conducted independently and should result in an assessment in accordance with applicable DoD regulations.

The M&S PM monitors the translation of the verified design into code, the data preparation, and all testing and V&V activities. By leading an effort to leverage the development, testing, and V&V efforts, the M&S PM can reduce excessive or repetitive testing, minimize costs, save time and resources, and synergize the overall effort.

Example:

- Code verification can be conducted by the Developer and monitored by the V&V Agent
- Unit testing can be coordinated with component verification tasks

Verify Implementation

Implementation verification is conducted to determine the degree to which the code conforms to the design, and to assess the quality (e.g., fidelity, accuracy) of the input data and the appropriateness of their preparation for use in the simulation. It involves several tasks that are frequently conducted by the Developer because they are closely associated with DT (e.g., code verification). The M&S PM should know who is

responsible for conducting each of the tasks (i.e., V&V Agent, Developer, or DT&E) to ensure resources are allocated appropriately.

Validate Results

Results validation determines how closely the results of the simulation match the referent. It is accomplished primarily through

- **testing** -- the simulation is executed using the actual data and the results are compared to validation data that have either been prepared by SMEs or obtained from the results of live tests, similar simulations, or appropriate historical events
- **face validation** -- SMEs review the performance and results of the actual execution

The M&S PM should allocate resources to the V&V Agent to conduct results validation and should ensure appropriate SMEs are available for face validation. When OT is involved, the M&S PM should encourage the V&V Agent and the OTA to work together and coordinate their efforts to increase the consistency of their results and reduce the impact on resources (e.g., unit testing and integration testing can be structured to support results validation).

Establishing the Relationship between Testing and V&V

Testing is a major analysis method employed in both simulation development and in V&V to assess correctness and fitness of the simulation. Many aspects of the testing environment for both DT and OT (e.g., scenarios, data, tools, measures, metrics) have great commonality with V&V activities: DT is closely related to implementation verification; OT is closely related to results validation.

The M&S PM should encourage a close relationship between the testers and the V&V Agent and should ensure the V&V Agent has access to the results of all testing that has been conducted. Every attempt should be made to leverage testing and V&V tasks. Sharing the testing environment can help reduce costs and resource expenditures as well as help ensure greater consistency among test and verification results (e.g., using the same tests, scenarios, and/or data reduces the risk of incorrect or inconsistent testing). (See the reference document on T&E and V&V Integration for additional information.)

Assessing Test and Validation Results

Based on the results of the V&V and testing efforts, problems are assessed to determine what changes need to be made.

- If changes are needed because of errors in either the code or data, the M&S PM works with the Developer to determine the changes needed.

- If changes are needed because of inconsistencies or ambiguities in the requirements, the M&S PM works with the User to resolve the problems.

Decisions need to be made based on trade-offs between the ability of the simulation to meet all the needs of the application and the ability of the development process to meet budget, schedule, or other objectives-driven constraints. If simulation capabilities appear inadequate to meet the needs of the application, then the PM works with the User and Developer to determine what alternative courses of action are available based on the risks involved:

- Is the level of risk associated with the simulation acceptable for the application?
- Should changes be made in the simulation to decrease the risk?
- Should requirements and associated criteria be modified to minimize the problem?

Although the M&S PM participates in this assessment, the User determines which alternative to take. Once a new course of action has been determined, the M&S PM adjusts schedules, plans, and resource allocations accordingly.

Prepare M&S for Use Phase

Accreditation

Accreditation addresses the question of whether the simulation should be used for the specified application. Although accreditation is often perceived as occurring at the end of a development process, the actual assessment process should begin as early as possible to ensure that V&V and testing activities provide appropriate and sufficient information to support the accreditation decision (see the [VV&A in New M&S Development](#) figure [p. 19]). The M&S PM provides information regarding schedules, milestones, plans, and products, including any designated reporting formats the Accreditation Agent should employ. In turn, the M&S PM reviews the accreditation information needs to ensure the necessary information can be obtained from the development and V&V activities planned. If the information needed cannot be obtained from the planned activities, then the M&S PM should apply additional resources to obtain it.

The Accreditation Agent assesses the evidence collected and prepares an accreditation recommendation for the User. If changes in the simulation are needed, the M&S PM should coordinate the plans and allocate the resources to address the simulation's deficiencies. Similarly, if additional information is needed about the simulation, the M&S PM should provide resources to obtain the information. If the accreditation decision is for full or limited accreditation, the M&S PM oversees the assemblage of the simulation for use.

Additional Major Considerations

Configuration Management

Configuration management occurs throughout the entire life cycle of a simulation. It is the process through which the integrity, consistency, and continuity of simulation development, upgrades, and maintenance are recorded, communicated, and maintained. A well-structured and well-maintained configuration management process provides the foundation necessary for version control.

As the manager of the new simulation development program, the M&S PM can establish a solid configuration management foundation by ensuring that all products and artifacts produced throughout the development process capture the necessary information in a format appropriate for archiving. Unique identifiers should be used to indicate information sources (e.g., development, testing, VV&A) and model versions.

As a primary user of the information maintained by configuration management, the V&V Agent should make sure the review results, problem reports, test results, and recommendations generated during the V&V process are properly formatted and integrated into the configuration management system. To facilitate the configuration management process, the V&V Agent should

- review the process to be employed to baseline the conceptual model, design, and code
- review change requests for any high-risk representation
- participate in performance benchmarking tests for high-risk representations

The M&S PM should ensure that the Developer knows the V&V Agent is empowered to perform these reviews.

Software and V&V Tools

Tool selection³⁹ has a strong impact on the return on investment and efficiency of both the development and V&V efforts. Whenever possible, the M&S PM should select tools that are suitable for both simulation development and V&V activities. Tools should be selected that support requirements traceability and documentation through all phases of the development process up to and including archiving.

Traceability, the ability to track how an M&S requirement is being met, from definition through implementation, is fundamental to the V&V effort. Traceability increases the likelihood that problems will be detected and resolved at the earliest and most economical stage possible. Although it is unusual to have an integrated environment

³⁹ See the reference document on V&V Tools for additional information.

that allows seamless movement from requirements to conceptual model to design to implementation, it is not impossible.

| Requirements Traceability | |
|-----------------------------|---|
| M&S Requirements | <ul style="list-style-type: none">• Verified M&S requirements serve as the foundation of the conceptual model. They should be assigned unique identifiers to be used to trace them through design and implementation |
| Conceptual Model | <ul style="list-style-type: none">• The validated conceptual model establishes the entities, behaviors, and relationships needed in the simulation and is traceable back to the verified M&S requirements |
| High-Level Design | <ul style="list-style-type: none">• High-level design transitions the validated conceptual model into system specifications that are traceable back to the validated conceptual model and the M&S requirements |
| Detailed Design | <ul style="list-style-type: none">• Detailed design adds all the attributes, parameters, and algorithms plus the data needed that are traceable back to the verified high-level design, validated conceptual model, and verified M&S requirements |
| Code | <ul style="list-style-type: none">• The verified design is converted into code and validated. The validated implementation is traceable back to the verified design, validated conceptual model, and verified M&S requirements |

Example:

Because of problems with various tools early in JWARS development, the decision was made to use a flow chart depiction of the Enterprise Model to serve as a surrogate Functional Description of the Mission Space (FDMS).⁴⁰ However, the flow chart diagrams were stand-alone and could not be automatically linked or tied to any other artifact. The diagrams were based on Joint Application Design (JAD) products that described each thread and were used to support the High Level Design, but the interface was manual and could not always be done consistently. This problem was identified during the V&V effort, which showed that because of these incompatibilities, the requirements could not be consistently linked to either the predesign products or design products (i.e., traceability was not possible). To address this problem, the JWARS Developer converted to a better tool that provided the necessary linkage and allowed traceability and manual conversions in their development process.

The M&S PM should also encourage the use of both tools and data systems that support documentation requirements and archiving. If a large number of high-risk representations are involved or the simulation is large and complex, the M&S PM may need to allocate additional resources to the V&V effort for purchase of appropriate tools.

Information Library

⁴⁰ Designated as the Conceptual Model of the Mission Space (CMMS) in DoD 5000.59-P, the *DoD M&S Master Plan*. The term CMMS has officially been changed to FDMS.

To increase efficiency, the M&S PM should collect and assemble reference material and information for use during the development process. This will ensure that all participants have access to the same information and should reduce the need for independent literature searches. Typical information to be included is listed in the table below.

| Information Library |
|--|
| • VV&A plans, reports, data, deliverables, and working papers |
| • Development change proposals and deliverables (excluding internal developer documentation) |
| • Knowledge acquisition information (reference books, papers, and materials) |
| • User domain information (source documents pertaining to the systems being modeled) |
| • Test descriptions |
| • Data descriptions (e.g., metadata) |
| • Additional information used in planning the application |

One method to ensure the availability of this information is to create a central library or archive of all draft and final products and make it available to the V&V Agent and other participants (e.g., SMEs, Accreditation Agent, M&S PM, and Users). Libraries of this type are typically a combination of hard copy documents and electronically stored media. (See also the section on [Documentation Requirements](#) [p. 38])

Software Library

The software library contains the official releases of the simulation and instance data used in the application. It should also contain the validation data and test data from every test conducted (together with test descriptions), regardless of who ran it and for what purpose. The objective of this pool of information is to be able to recreate tests and to quickly associate their software release, data, test cases, procedures, and scripts.

Security

Security is primarily the M&S PM's responsibility. The development effort should be organized to accommodate proper security measures, such as:

- the physical location of equipment, data, documentation, and work stations should be secure from the dangers of theft and vandalism
- when classified information is involved, all participants in the development process should have the necessary clearances for their assigned tasks and for the information they may encounter

- all applicable regulations and policies should be followed (e.g., visitor escorts, facility lock-up, need-to-know information sharing)

Safeguarding classified data is often the M&S PM's most important security consideration. In most (but not necessarily all) cases, simulation code by itself is unclassified; however, when combined with classified data, the simulation becomes classified.

Instance data⁴¹ and scenario information may also involve different levels of classification, representing an additional challenge for partitioning the development effort and for coordinating testing and V&V activities. The M&S PM should encourage the Developer to keep the simulation and the elements of the simulation unclassified for as long as possible. When classified data are necessary, the M&S PM should ensure that those participating in all activities (e.g., development, testing, V&V) have the required clearances to gain access to the simulation.

Example:

When classified (e.g., Secret, Top Secret) input data are needed to provide the level of detail and accuracy required for the application, firewalls may need to be established and unclassified surrogate data may need to be obtained because all participants in the development process (e.g., testers, coders, technicians) may not be cleared for access to classified data.

One of the major challenges associated with data is protecting them from accidental or intentional contamination, mishandling, or misuse. The V&V effort should include data V&V activities that can provide evidence of data contamination as well as information about the appropriateness of data, both real and surrogate, for their intended use.

M&S PM's Relationship with Other Roles

Overview

The M&S PM's most overarching concern is the credibility of the simulation when development is complete. The M&S PM, V&V Agent, and User are important team members in assuring fitness for purpose. The Developer builds the simulation based on the M&S requirements provided by the User. The V&V Agent gathers evidence of the simulation's fitness for the application. The M&S PM orchestrates the entire process and determines where the risk to credibility is greatest. The M&S PM, Developer, and V&V Agent should collaborate to control technical risk and ensure the correctness of the simulation's representation. The M&S PM should also collaborate with the Developer, User, and V&V Agent to control management risk and take measures to ensure the

⁴¹ See the reference document on M&S Data Concepts and Terms.

program is properly staffed and that adequate time and resources are available to complete the job.

M&S PM's Relationship with the User

The User is the primary source of M&S requirements, particularly user and problem domain requirements. Typically, the User is the primary funder for the overall development and serves as the primary decision-maker for all changes that impact the ability of the simulation to address the application. The M&S PM provides the User with information about the status of the development and incorporates User recommendations regarding changes.

In a major development program when multiple (future) Users are anticipated, the M&S PM may establish a Users group to help define requirements, assess risks, and serve as SMEs for the user and problem domains. Members of the Users group can also assist the Accreditation Agent in the development of the acceptability criteria that the simulation must meet to achieve accreditation.

M&S PM's Relationship with the M&S Developer

The M&S PM and Developer work together to plan and execute the development process. Good communication between the M&S PM and Developer is necessary if the development effort is to succeed. The Developer can assist the M&S PM during the risk assessment by providing insights on potential risks, such as

- M&S requirements that are unclear or poorly articulated. These impact the Developer's ability to develop appropriate conceptual models, designs, and code.
- M&S requirements that are highly complex and require more attention than normal. These impact the schedule and allocation of resources.
- Complex representations for which little or no previous work has been done. These require significant input from SMEs and impact the schedule, allocation of resources, and budget.

During the planning phase, the Developer should also provide guidance on staffing and resourcing and the selection and application of tools and should work with the M&S PM to identify focal areas for the V&V effort. Conversely, the M&S PM should monitor the development and V&V activities and participate in information exchanges to ensure coordination between them and instill an atmosphere of respect and cooperation among the participants.

The M&S PM should ensure that V&V-related responsibilities of the Developer are specified in any contractual statements of work (SOW) for every phase of the development life cycle. The M&S PM and the Developer should work together closely

to ensure that total resources (schedule, budget, and staffing) are focused on the right issues at the right time to successfully conclude the project. This responsibility includes ensuring that V&V resources are focused appropriately.

M&S PM's Relationship with the V&V Agent

Normally, the M&S PM is responsible for selecting the V&V Agent and allocating funding for the V&V effort. The M&S PM should also provide the V&V Agent with recommendations on V&V priorities based on the risk assessment and assist with the development of the V&V plan. The M&S PM serves as the final approval authority on the V&V plan; but in some cases, the M&S PM may prepare the plan and designate a V&V Agent to execute it. Ideally, the M&S PM designates the V&V Agent as soon as the development effort has begun so the V&V effort can be aligned with the development process. However, if a V&V Agent cannot be selected until later, then the M&S PM should be responsible for ensuring appropriate V&V tasks are performed (e.g., M&S requirements verification, planning) in a timely manner. Once the V&V Agent is on board, the M&S PM should allocate time and resources for the V&V Agent to examine the V&V work performed in order to establish a foundation for the remainder of the V&V effort.

The M&S PM should also facilitate coordination between the V&V Agent and the Developer by encouraging a cooperative and respectful atmosphere and monitoring the activities and information exchanges. The M&S PM should

- encourage the sharing of tools to ensure consistency in the artifacts produced and to reduce costs
- work with the V&V Agent and Developer to determine the division of responsibility in verification testing (e.g., who performs code verification)
- identify products and specify formats to ensure appropriate information is collected and saved in a usable form
- coordinate development, testing, and V&V schedules to ensure facilities, tools, personnel, etc. are available when needed

M&S PM's Relationship with the Accreditation Agent

The Accreditation Agent serves as the User representative working to establish the simulation's fitness for purpose. The Accreditation Agent is critical for establishing the acceptability criteria by which the simulation capability will be judged and for identifying the information the V&V effort needs to produce for the accreditation assessment. The M&S PM provides information regarding costs, scheduling, resource needs, etc. for the accreditation assessment, and establishes formats for the documents produced during development that serve as the foundation for configuration management of the simulation. The M&S PM should work with the Accreditation Agent to ensure there is sufficient information from the development and V&V efforts to perform a satisfactory

accreditation assessment and the configuration management formats are appropriate for capturing accreditation assessment information and for preparing the final accreditation report.

M&S PM's Relationship with Others

Test and Evaluation

There is great commonality between simulation testing activities (DT and OT) and V&V (e.g., scenarios, data, tools, measures, metrics, SMEs, equipment). The M&S PM should lead the effort to identify and exploit leveraging opportunities by coordinating plans and activities. The M&S PM should monitor the DT activities (planning, preparation, execution, and reporting) and ensure the V&V Agent and other interested outside agencies, such as the OTA, are included in the testing process. The V&V Agent should be allowed to review test plans, participate in the actual testing, and review the results. During OT, the M&S PM should ensure the V&V Agent has opportunities to be involved as well. If properly planned and coordinated, the OT activities can augment and support the validation effort.⁴²

Documentation Requirements

As a part of [configuration management](#) process [p. 32], the M&S PM should oversee the collection and archiving of essential V&V information, ensuring that an accurate, comprehensive record of the V&V activities is kept. Beginning with the initial V&V Plan, the documentation should be specific enough to demonstrate the rigor of the V&V events and comprehensive enough to describe the overall V&V process that was executed.

Although each development process will vary in its specific implementations, two general ideas should always be considered when determining which parts of the V&V effort should be archived: **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 during the development process. As the simulation moves into later stages of its life cycle, questions may be asked about what issues had been raised and how they were resolved during development.

One method to ensure the availability of this information is to create a central archive of all draft and final products and make it available to the V&V Agent and other participants (e.g., SMEs, Accreditation Agent, M&S PM, and Users). This archive should include information created during simulation development to support the V&V effort as well as information about the V&V effort (see [Appendix D](#)). Because a Developer may not

⁴² See the reference document on T&E and V&V Integration for additional information.

collect and save documentation beyond what is specified by contract, the M&S PM should be careful to formalize documentation requirements as product specifications in all contractual agreements.

Ideally, the information supporting the development and V&V processes is collected by the Developer and V&V Agent as it is acquired and presented to the M&S PM and User upon delivery of the accredited simulation. However, the M&S PM should ensure that the information being collected adequately demonstrates the accomplishments of both the V&V and development processes (when and how goals were accomplished) and articulates the problems and issues uncovered (obstacles were encountered and the methods, successful and unsuccessful, used to resolve them).

Guidelines to facilitate this effort are shown in the table below.

| M&S PM Guidelines to Facilitate Documentation |
|--|
| Establish the ground rules |
| <ul style="list-style-type: none">• The M&S PM should identify documentation needs in collaboration with the Developer and V&V Agent and establish formats so the artifacts are usable by both current and future users. Encourage the Developer and V&V Agent to be meticulous and prompt in their recording efforts. |
| Be realistic about the amount to be collected |
| <ul style="list-style-type: none">• Identify the need for each piece of information to be collected and minimize unnecessary duplication. Be clear about what information does not need to be saved; however, when in doubt, save. |
| Document and collect as it happens |
| <ul style="list-style-type: none">• It is much easier to record important information and events as they happen than it is to try to go back after the fact and piece together what happened. |
| Be the enforcer |
| <ul style="list-style-type: none">• When the stress of impending deadlines sets in, the M&S PM should ensure that the archiving process is not forgotten. The M&S PM is responsible for making sure that things are done right the first time to whatever extent possible. |

Establishing a VV&A archive during simulation development should facilitate subsequent model enhancements and modifications. Although each use of a simulation requires its own VV&A effort, the information contained in such an archive can help potential Users understand strengths and limitations of a simulation and its fitness for a specific use and provide the historical information needed in the accreditation assessment of a legacy simulation.⁴³ This information, in turn, will help determine if the simulation will be used, what needs to be done to prepare it for use, and what V&V activities may be essential for evaluating its fitness for the new application.

⁴³ See the core document on the Accreditation Agent Role in the VV&A of a Legacy Simulation.

Cost Implications and Resourcing

Costs are, of course, a legitimate concern for the M&S PM. As a general rule, the more V&V activities are integrated into the development process, the easier it is to control costs. The objective is to make the V&V effort as cost-effective as possible.

Cost Factors

The major V&V cost factors are the personnel, the tools they employ, and data.

Personnel

The personnel associated with a V&V effort includes the V&V Agent, members of the V&V team, and SMEs⁴⁴ that may be required to perform specific tasks or provide specific information. The greater the complexity of the application, the greater the need for different kinds of expertise during the V&V effort.

Personnel costs should be directly related to the type of labor they actually perform as well as the length of time involved in performing it. Because planning can be accomplished with a relatively small core group, a full V&V team may not need to be assembled until the actual V&V tasks need to be performed and then individual team members may be brought in just to perform specific tasks.

At a minimum, SME costs would consist of travel expenses. However, it is becoming more common for SMEs to require payment for their time as well. To minimize SME costs, alternatives to frequent face-to-face meetings should be considered (e.g., teleconferences, electronic [e-mail and web-based] discussions). Careful planning and scheduling of SME meetings and the preparation and advanced distribution of read-ahead packages can also ensure efficient use of SME time.

Tools

Tool selection⁴⁵ has a strong impact on the return on investment and efficiency of both the development and V&V efforts. Whenever possible, the M&S PM should encourage the Developer to select tools that are suitable for both simulation development and verification and validation activities.

Sharing tools can both reduce costs and avoid irregularities that arise due to tool inconsistencies rather than actual problems with the simulation.

- CASE tools should support requirements traceability and documentation through all phases of the development process up to and including archiving.

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

⁴⁵ See the reference document on V&V Tools for additional information.

- Testing tools, whether purchased or built, should be evaluated for use in V&V tasks to reduce costs and ensure consistency in the testing environment.

Some desirable features to look for in selecting tools are listed in the table below.

| Desirable Tool Features |
|--|
| • Tools that provide fields for making text annotations |
| • Tools that can feed relational databases, ideally allowing the user to select the data needed and converting it to a standard file for exporting |
| • Tools that allow design elements and code chunks to be tagged or otherwise associated with a requirement |
| • Tools and data systems that support archiving |
| • Tools that allow traceability |

Data

Validation data (i.e., test data) are needed for all testing and validation activities. In results validation, the results of a simulation are compared to the referent. Once the referent is defined, data describing the referent need to be identified and collected or developed.⁴⁶ Real-world empirical data are preferable; however, when these are unavailable, test scenarios are developed and SMEs are asked to provide reasonable, expected results. The M&S PM should ensure that sufficient funding is available so validation data can be obtained and/or created and data V&V efforts can be conducted on all data involved in the development and use of the simulation.

Controlling Costs

Detailed Planning

Detailed and flexible planning increases the chance that the V&V process will be conducted in the most cost-effective way. Comprehensive risk assessments show where V&V resources should be focused to provide the most good and serve as the foundation for cost estimates. Adjustments should be made as the simulation and problem domain requirements emerge and priorities are more clearly defined. As the conceptual model emerges, the initial requirements-based plan should be updated and refined again.

Monitoring Execution

⁴⁶ See the special topics on Fidelity, Validation, and Conceptual Model Development and Validation for more information on referents.

During execution, unexpected complications may alter the plan and divert V&V resources. New cost information based on more specific information (e.g., time required to complete specific activities) should be collected and compared to the initial estimates. Detailed monitoring should allow the M&S PM to push the work forward and make midcourse corrections as needed.

References

External Links in This Document

Software Engineering Institute (SEI), *Capability Maturity Model for Software*, Carnegie Mellon, <http://www.sei.cmu.edu/cmm/>

RPG References in This Document

select menu: *RPG Core Documents*, select item: "Accreditation Agent Role in the VV&A of Legacy Simulations"

select menu: *RPG Core Documents*, select item: "User Role in the VV&A of New Simulations"

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

select menu: *RPG Diagrams*, select item: "Typical Roles and Their Responsibilities"

select menu: "Key Concepts"

select menu: *RPG Reference Documents*, select item: "M&S Data Concepts and Terms"

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 New Simulations"

select menu: *RPG Special Topics*, select item: "Fidelity"

select menu: *RPG Special Topics*, select item: "Measures"

select menu: *RPG Special Topics*, select item: "Paradigms for M&S Development"

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 Special Topics*, select item: "Validation"

select menu: *RPG Templates*, select item: "Data Quality Templates"

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In the web-based version of this document, the appendix below appears as a hot link in the Plan M&S Development Phase section.

Appendix A: Critical Development Elements and Issues

The critical elements of the development process lay the foundation for identifying necessary V&V activities. The development elements and issues identified in the table below are relatively generic and apply to all simulations. Additional development issues should be added based on the results of the risk analysis.

| Critical Elements | Development Issues |
|--|--|
| Purpose of the application | <ul style="list-style-type: none"> • Why is the simulation being built? |
| Objectives | <ul style="list-style-type: none"> • What are the representational requirements (command and control analysis, training battle staffs, developing and assessing system performance to support acquisition, etc.)? |
| Fidelity | <ul style="list-style-type: none"> • Has the level of fidelity needed for the intended application been determined? • Have the components that will comprise it been identified? |
| M&S requirements, metrics, acceptability criteria | <ul style="list-style-type: none"> • Has a set of requirements been developed by potential users of the simulation that identifies the entities, processes, tasks, and behaviors? • Do these requirements include appropriate metrics that can lead to building valid and quantitative acceptability criteria? |
| Conceptual model | <ul style="list-style-type: none"> • Is a conceptual model being developed? • Is the process in place to analyze, decompose, and document the entities, processes, tasks, interactions, and data required to accurately reflect the real world entities, processes, and interactions? |
| Cause-and-effect relationships | <ul style="list-style-type: none"> • Are the relationships adequately defined for each major representational requirement? |
| Data | <ul style="list-style-type: none"> • Are the data needs well defined and understood? • Does appropriate data exist? |
| Size and scope of development | <ul style="list-style-type: none"> • What is the anticipated magnitude of the development with respect to functionality, modules, objects, lines of code, function points, etc.? |
| Development paradigm | <ul style="list-style-type: none"> • Is there a software development paradigm being used? Is it appropriate? • What development activities are required for each phase? |
| Scheduling | <ul style="list-style-type: none"> • Is sufficient time available to complete each phase of development? |
| Domain SMEs | <ul style="list-style-type: none"> • Problem domain: Is the functional (e.g., military) expertise available that is required to analyze, decompose, and support definition of major problem domain representations? |
| | <ul style="list-style-type: none"> • User domain: Is the user domain expertise available to analyze, decompose, and support definition of the necessary aspects of the User's environment? |
| | <ul style="list-style-type: none"> • Simulation domain: Is the simulation domain expertise available to analyze, decompose, and support definition of the simulation engine requirements (e.g., time management, event management, interaction management)? |
| Accreditation status | <ul style="list-style-type: none"> • Has an Accreditation Agent been selected to establish acceptability criteria and perform the accreditation assessment? |

In the web-based version of this document, the appendix below appears as a hot link in the Plan M&S Development Phase section.

Appendix B: V&V Issues Associated with Critical Development Elements

The V&V issues associated with critical development elements identified in the table below are relatively generic and apply to all simulations. Additional V&V issues should be added based on the results of the risk analysis.

| Elements | V&V Issues |
|-------------------------------|---|
| M&S requirements | <ul style="list-style-type: none"> • Are the requirements well defined with representational objectives for each that include entities, processes, behaviors, tasks, interactions? |
| Acceptability criteria | <ul style="list-style-type: none"> • Have metrics acceptability criteria been defined and do they address the (problem, user, simulation) domain requirements of the application? |
| Conceptual model | <ul style="list-style-type: none"> • Is there a documented conceptualization of the entities, processes, tasks, interactions, and data needed to address the M&S requirements? • Does it accurately and adequately define the cause-and-effect relationships for each major representational requirement? |
| Design | <ul style="list-style-type: none"> • Is the design based on elements of the conceptual model that are traceable to the M&S requirements? • Are appropriate behavioral representations enabled? |
| Data | <ul style="list-style-type: none"> • Are authoritative data sources identified? • Are appropriate data available? • Are valid methods used to prepare the data for use in the simulation? • Are the data formatted to validly meet needs of the simulation's algorithms? |
| Test planning | <ul style="list-style-type: none"> • Do test objectives reflect the M&S requirements? |
| Code | <ul style="list-style-type: none"> • Are the algorithms working • Do the algorithms reflect M&S requirements? • Do software units integrate into a coherent, working simulation? |
| V&V activities | <ul style="list-style-type: none"> • Have the verification and validation tasks been integrated throughout the development process? |
| Domain SMEs | <ul style="list-style-type: none"> • Problem domain: Is the functional (e.g., military) expertise available that is required to analyze major problem domain representations? |
| | <ul style="list-style-type: none"> • User domain: Is the user domain expertise available to analyze the necessary aspects of the User's environment? |
| | <ul style="list-style-type: none"> • Simulation domain: Is the simulation domain expertise available to analyze aspects of the simulation domain requirements (e.g., time, event, and interaction management)? |
| Accreditation status | <ul style="list-style-type: none"> • Has an Accreditation Agent been selected to establish acceptability criteria, identify accreditation information needs, and perform the accreditation assessment? |

In the web-based version of this document, the appendix below appears as a hot link in the Plan M&S Development Phase section.

Appendix C: M&S PM Scheduling Process

| Basic M&S PM Scheduling Process |
|--|
| Develop a preliminary schedule based on the average time expected to complete each step in the development process as determined by the M&S requirements and the development paradigm |
| <ul style="list-style-type: none">• The M&S requirements determine what development tasks need to be done; the paradigm determines when they take place and how often they may need to be done• V&V activities normally affect the development schedule by<ul style="list-style-type: none">– identifying problems that should be resolved before or during simulation development– requiring time and resources (people, equipment, information) from the development effort for reviews, tests, training• Identify exit criteria for each development and V&V task |
| Build in some flexibility |
| <ul style="list-style-type: none">• Include additional time to accommodate unexpected problems (equipment breakdowns, data delays, new or modified requirements to address)• Allow additional time to accommodate high-risk areas and unexpected issues identified by the risk assessment. Problems are more likely to occur in high-risk areas and more likely to be harder to resolve, taking more time and resources• Be prepared to rechannel resources toward important problems as they arise, but be careful to discriminate between the really important issues and those that do not need as much attention• Consult with computer specialists and system engineers to obtain appropriate estimates for the amount of time required to build interfaces, etc. including associated risks identified during the risk assessment and adjust the schedule accordingly• Consult with subject matter and technical experts to obtain estimates for the amount of time needed to address each of the high-risk M&S requirements and adjust the schedule accordingly |
| Review the remaining (lower risk) M&S requirements and estimate the amount of time needed to address each |
| <ul style="list-style-type: none">• Determine if any can be addressed in less time and lower costs by<ul style="list-style-type: none">– using legacy code– using different data– combining tasks– adopting different V&V techniques (e.g., face validation instead of testing)• Minimize the V&V effort on low-risk requirements by<ul style="list-style-type: none">– combining tasks– adopting different V&V techniques (e.g., face validation instead of testing)• Check to ensure that each component is essential in meeting the application's objectives and is traceable to the M&S requirements |

| Basic M&S PM Scheduling Process |
|--|
| Review the schedule again with technical experts and software engineers to ensure adequate time is allocated for integrating the components. |
| <ul style="list-style-type: none">• Regularly review the schedule and adjust for unforeseen problems |

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

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 | |
|---|--|
| | Products and Information |
| M&S Requirement Refinement | <ul style="list-style-type: none"> • definitions • metrics, measures, and acceptability criteria • requirement trail through the conceptual model and design to code • relationships to specific entities, processes, behaviors, events, or outputs • modifications/revisions required and accomplished |
| Planning | <ul style="list-style-type: none"> • problem definition and objectives • M&S development plan • V&V plan • accreditation plan • modifications/revisions required and accomplished |
| Conceptual Model | <ul style="list-style-type: none"> • validated annotated conceptual model • behaviors and interactions 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 | <ul style="list-style-type: none"> • annotated simulation design, preliminary and detailed • design entities (e.g., objects, attributes, parameters) mapping to conceptual model elements, objectives, requirements • verification techniques and results (e.g., functionality) • modifications/revisions required and accomplished |
| Implement and Test | <ul style="list-style-type: none"> • verified code • verification techniques and results (e.g., data, code) • testing techniques, data, scenarios (use cases), and results • data flow analysis • validation techniques, data, algorithms, scenarios (use cases), and results • modifications/revisions required and accomplished |
| Prepare for Use | <ul style="list-style-type: none"> • 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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