

## **Program Manager's Role in Verification, Validation and Accreditation (VV&A) of New Development**

The objective of this document is to describe the Modeling and Simulation (M&S) Program Manager's (PM) role and interests in the VV&A of a new simulation. The M&S PM is in charge of the programmatic 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, in coordination with the Developer
- Directing all aspects of the development, schedule, budget, contracting, and risk management

The M&S PM is concerned that the available resources be focused on bringing the project to a successful conclusion and that the simulation has credibility within the User community. The Verification and Validation (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 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.

### ***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 allocate resources to 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 resource allocation, regular risk assessments, and focus of V&V assets are important to a 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 assessment 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 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

Two basic types of risk are 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.

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 [Core Document>New Development>User](#) and [Advanced Topics>Special Topics>Risk and Its Impact on VV&A](#).

## Development Risk

There are two main categories of development risk: **management** and **technical**. Some texts identify three categories: management, scheduling, and technical. For the purposes of the document, scheduling is considered one type of management risk.

### Management Risk

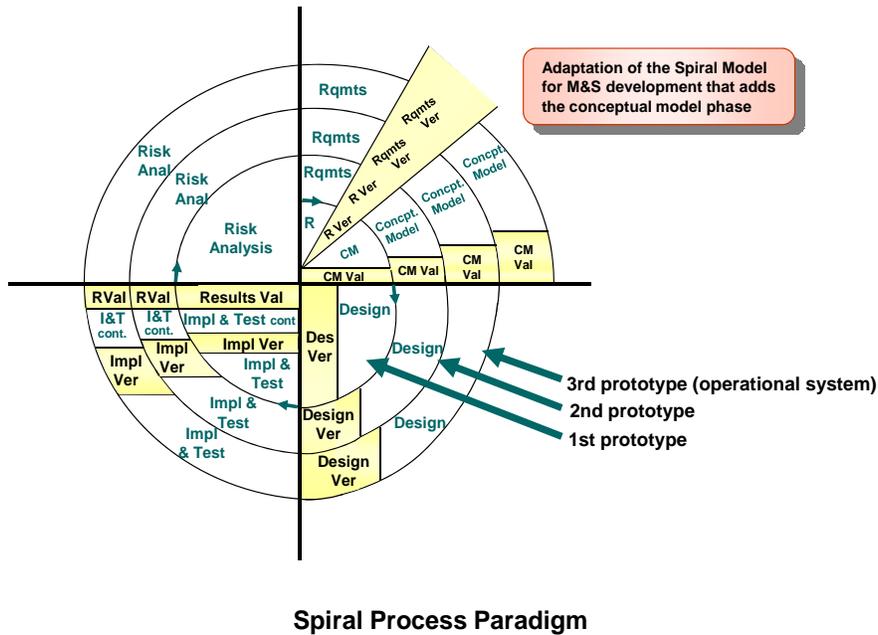
Management risk involves problems associated with scheduling, resources, and requirements. Elements of the development process that have a high probability of impacting the level of management risk include:

- **Requirements** – The state of the M&S requirements 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 evolving requirements.

As the representational requirements become more complex, the V&V activities become more critical. 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. For more information see [Advanced Topics>Special Topics>Requirements](#).

- **Development paradigm** – The paradigm 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. For more information see [Advanced Topics>Special Topics>Paradigms for M&S Development](#).

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- **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 that problems identified by the V&V activities can be addressed in a timely manner and so that 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?
• Are there sufficient resources (time, money, SMEs, equipment) to build the knowledge base?
• 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, some representations 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." Human decision-making representations function on their own during execution of the simulation.

- **Data** – Data 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 pedigrees in terms of the authoritative data sources, quality assurance information, and sufficient metadata to provide confidence in the data quality and fidelity.
  - Data can seldom be used in their original form, and the manipulation 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&V should be conducted as part of (or in concert with) the V&V process. The M&S PM should designate who is responsible for conducting the data V&V effort (e.g., the V&V Agent) and allocate appropriate resources.

For more information see [Resources>Reference Documents>M&S Data Concepts and Terms](#), [Resources>Templates>Data Quality Templates](#), and [Advanced Topics>Special Topics>Data V&V for New Simulations](#).

- **Software Integration** – Software integration presents some unique technical risks, particularly when a spiral development approach is used, where numerous modules and components are under independent development. 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 assessment 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"><li>• The User or designated representative categorizes the M&amp;S requirements by defining a set of possible consequences that can occur if a requirement is not adequately met.</li></ul>
<ul style="list-style-type: none"><li>• SMEs assign likely <b>causes</b> 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.</li></ul>
<ul style="list-style-type: none"><li>• The User and M&amp;S PM assess the impact for each failure category and rank the requirements on the basis of on the likely impact of failure.</li></ul>

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

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**Example:**

The Software Engineering Institute's Software Capability Maturity Model 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.<sup>1</sup> It is considered a de facto standard for assessing and improving software processes. It 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 model recommends early identification of and action to deal with high-risk project objectives.

The Capability Maturity Model process is one mechanism that can help identify and mitigate high-risk development problems and assess the quality of the simulation.<sup>1</sup>

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.

<b>V&amp;V Risk Mitigation</b>
<b>Assess the correctness and completeness of the representation:</b>
<ul style="list-style-type: none"><li>• Are all essential components or features represented?</li><li>• Is each traceable to an M&amp;S requirement?</li><li>• Does the Developer understand the required interactions and behaviors?</li><li>• 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?</li><li>• 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?</li></ul>
<b>Assess the accuracy of the representation:</b>
<ul style="list-style-type: none"><li>• Are the results consistent with real-world experience, as compared with the conceptual model and with SME opinion?</li></ul>
<b>Assess the overall risk (i.e., likelihood of failure):</b>
<ul style="list-style-type: none"><li>• What is the chance that the representation will fail and the requirement will not be met?</li></ul>
<b>Identify further mitigation measures:</b>
<ul style="list-style-type: none"><li>• What reasonable and prudent measures can be taken to lower the overall risk that are consistent with the schedule, budget, and expert resources available?</li></ul>

To accomplish most V&V tasks, a number of formal and informal V&V techniques can be employed. The technique 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.

For more information see [Advanced Topics>Special Topics>Risk and Its Impact on VV&A](#).

### ***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 that 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 that 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 its associated V&V activities
- Ensure that the V&V activities are properly integrated with development and test activities
- Ensure that the verification activities occur as part of a formal or semiformal review process and that the results of each activity are documented
- Provide adequate time in the schedule for V&V reviews and development responses
- Ensure that the V&V Agent is included in development and testing activities (e.g., M&S requirement reviews, code walkthroughs, operational testing, developmental testing)
- Continually examine trade-off situations (e.g., mitigating risk and increasing credibility versus resource allocation, budget, and scheduling constraints) 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

- Consider the tool needs of the V&V effort when selecting tools (when possible, the tools selected for development and testing should also support V&V activities)

**Example:**

Computer-aided software engineering 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 in funding and resources and integration of V&V with development activities. Additional challenges include incomplete requirements and objectives, incomplete or nonexistent conceptual model, formalized development products, rushed transition from design to implementation, and SME coordination and resourcing. These challenges are discussed in the following paragraphs.

#### **Balance**

The M&S PM should determine the proper balance of funding and allocation of resources between V&V activities and development to ensure that 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.

#### **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 decreases, because problems are identified too late to avoid impacting later development phases, increasing the cost of their correction.

#### **Incomplete Requirements and Objectives**

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 that the User requires

The M&S PM should work with the User to produce unambiguous and specific requirements early so that they can be verified and so that associated risks can be ascertained in time to be incorporated in initial plans and schedules. Because requirements definition and refinement is often an ongoing process that continues 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 model 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 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 Joint Warfare System 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 referent 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.

For more information see [Advanced Topics>Special Topics>Conceptual Model Development and Validation](#).

### **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

### **Rushed Transition from Design to Implementation**

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 for 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) 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 that their involvement is scheduled at appropriate times and that 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, it is becoming more common for SMEs to require payment for their time as well. To minimize SME costs, alternatives to frequent large 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

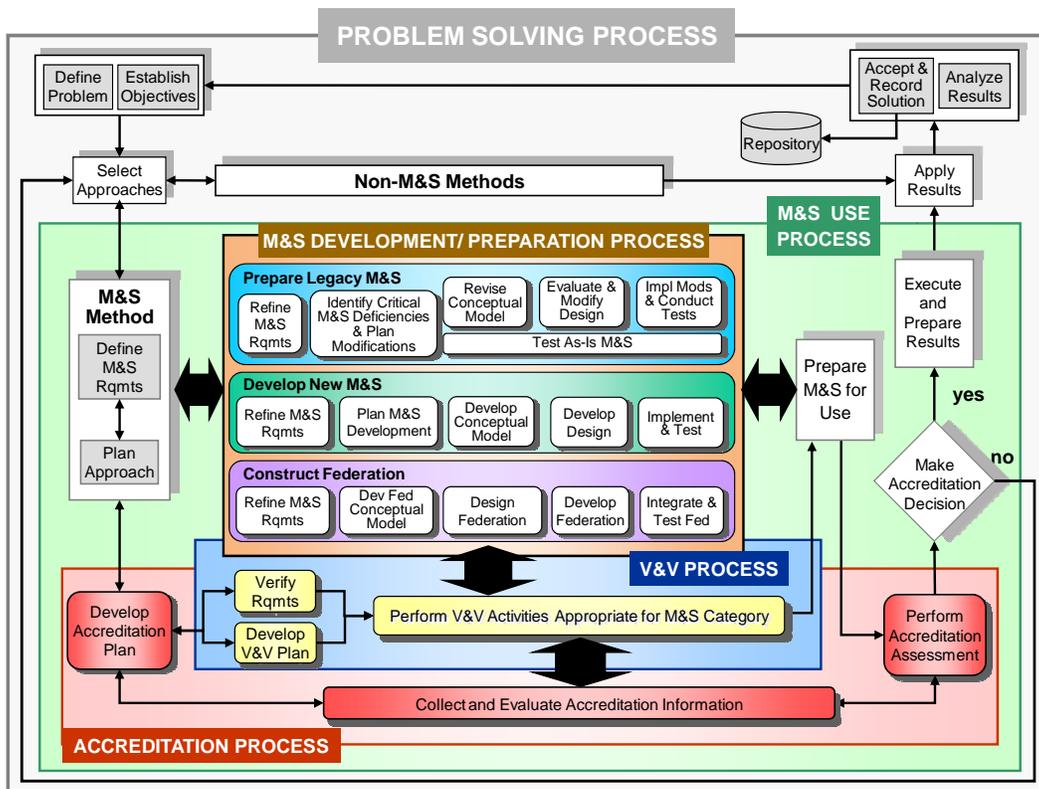
SME meetings and the preparation and advanced distribution of read-ahead packages can also ensure efficient use of SME time.

For more information see [Advanced Topics>Special Topics>Subject Matter Experts and VV&A](#).

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

### Problem Solving Process

The following diagram shows how the M&S life cycle fits into the overall Problem Solving Process. The diagram depicts the relationships between the **Problem Solving Process**, the **M&S Use Process**, the **M&S Development/Preparation Process**, the **V&V Process**, and the **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 completion of that process.



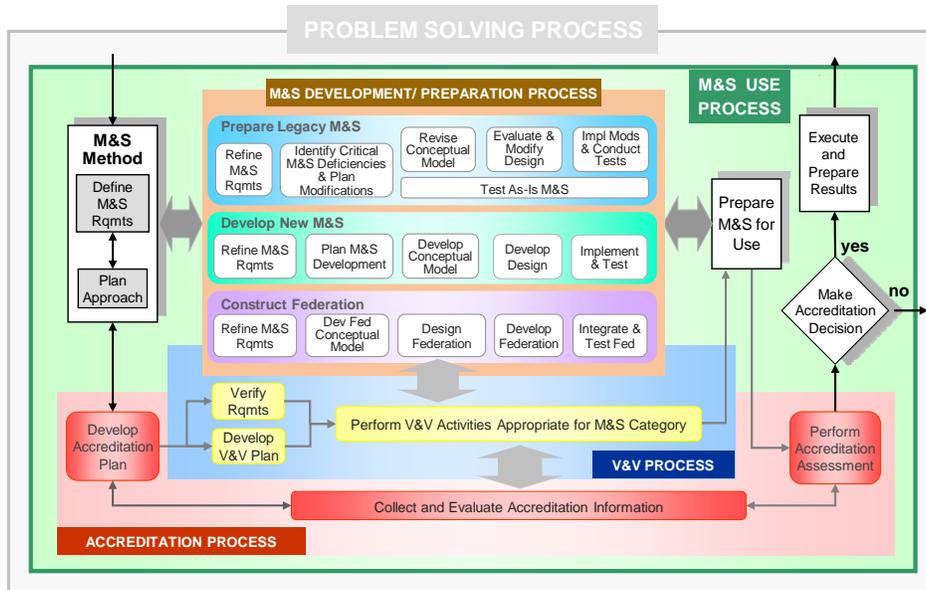
The Overall Problem Solving Process

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 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.

## 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.



**M&S Use Process in the Problem Solving Process**

At the beginning of this process, during the **M&S Methods** phase, M&S program management is initiated and an M&S PM is designated to oversee issues relating to cost, scheduling, resourcing, etc. 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.

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 activities are listed below and discussed in the following sections.

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

An analysis of the problem can help ensure that the right problem is being addressed and that 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 requirements 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"><li>• What information is needed to support the key problem decisions or to resolve the key problem issues?</li></ul>
<ul style="list-style-type: none"><li>• What specific simulation outputs relate to the information required?</li></ul>
<ul style="list-style-type: none"><li>• How good do these outputs need to be; i.e., what is the level of tolerance for uncertainty in the results?</li></ul>
<ul style="list-style-type: none"><li>• 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?</li></ul>

For more information see [Advanced Topics>Special Topics>Requirements](#).

## Plan Approach

### *Assessing Risk*

One of the most critical functions impacting V&V planning is the assessment of risks. A risk assessment 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.

<b>The M&amp;S PM's Role in Risk Assessment</b>
<ul style="list-style-type: none"><li>• Identify SMEs</li></ul>
<ul style="list-style-type: none"><li>• Solicit information and assistance from similar successful development efforts</li></ul>
<ul style="list-style-type: none"><li>• Select the Developer and V&amp;V Agent in time to participate in the mitigation and, if possible, in the risk assessment process</li></ul>
<ul style="list-style-type: none"><li>• Evaluate the development paradigm to determine if it is sufficient</li></ul>
<ul style="list-style-type: none"><li>• Explore options in the development process to accommodate high-risk areas</li></ul>
<ul style="list-style-type: none"><li>• Adjust resource allocations and timelines to ensure that high-risk areas receive appropriate attention</li></ul>
<ul style="list-style-type: none"><li>• Schedule risk assessment reviews at appropriate times throughout the development process</li></ul>
<ul style="list-style-type: none"><li>• Assess data risks by reviewing the availability of authoritative data</li></ul>

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 keep the development focused on the priorities.

### *Establishing Contractual Agreements*

The M&S PM is responsible for designating both the Developer and the V&V Agent and for overseeing all contractual agreements relating to the development program. The M&S PM should ensure that the contractual statement of work involves 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.

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Typical statement of work Information	
• Problem statement	Objectives to be accomplished by the statement of work
• 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 accomplishment of objectives
• Products	Products and artifacts to be produced
• Milestones	Time period for delivering products

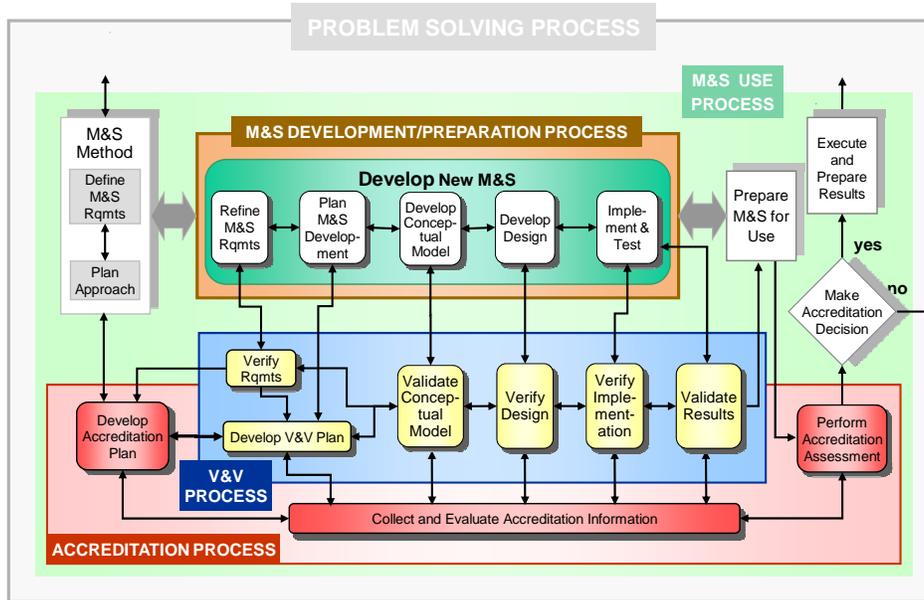
The information provided should be understandable with minimal inference. Questions should be resolved immediately and contracts modified to clarify issues. The products and artifacts identified should include all those needed during subsequent phases of development, those needed for testing and the 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, select the development paradigm, 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 figure below, 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, as well as in the associated accreditation process, is discussed in the following section.

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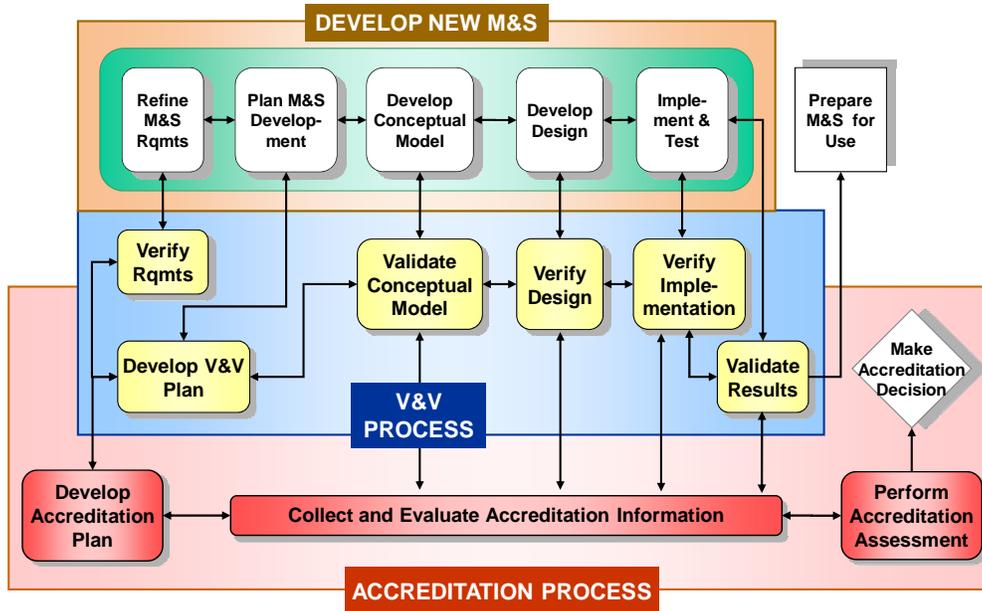


M&S Development/Preparation Process for New M&S

**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 is primarily one of oversight and resource allocation for both planning the V&V effort and implementing the V&V plan (see [Resources>Diagrams>Typical Roles and Their Responsibilities](#) and [Key Concepts](#)). 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 diagrams below. These phases and activities are listed below and discussed in the following paragraphs.



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 requirements 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
<b>Problem, user, and simulation domains should be addressed in the M&amp;S requirements.</b>
<ul style="list-style-type: none"> <li>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.</li> </ul>
<b>Requirements should be measurable.</b>
<ul style="list-style-type: none"> <li>Measures (e.g., measures of performance, measures of effectiveness) that derive logically from generalized M&amp;S requirements statements are usually the best approach to building adequate and accurate requirements.</li> </ul>
<b>M&amp;S requirements should be traceable.</b>
<ul style="list-style-type: none"> <li>Each requirement and its component parts (e.g., metrics, definition) should be traceable to an objective.</li> </ul>

<b>Major Concerns During M&amp;S Requirements Refinement (continued)</b>
<b>Requirements databases should support traceability throughout the development process.</b>
<ul style="list-style-type: none"><li>Records should be unique so that, as the conceptual model, design, and implementation phases proceed, the Developer can demonstrate and the V&amp;V Agent can verify the need for each product through reference to the requirement.</li></ul>
<b>Acceptability criteria should be developed to describe how the simulation should perform when completed.</b>
<ul style="list-style-type: none"><li>This effort should be led by the Accreditation Agent with participation from the User, M&amp;S PM, Developer, V&amp;V Agent, and designated SMEs.</li><li>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.</li></ul>
<b>Required data should be explicitly identified and the search for authoritative sources of data begun immediately.</b>
<ul style="list-style-type: none"><li>Obtaining data that fit the needs of the application and simulation is frequently high risk.</li><li>Data acquisition and validation activities should begin as soon as potential data sources are identified on the basis of an assessment of the types of data needed.</li><li>Additional data analysis should be performed 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.</li></ul>

## 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
  - 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.

<b>Simulation Profiling Information</b>
• 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
• Miscellaneous planning information (these are specific to the use case and the expected amount of simulation preparation involved)
• 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
• 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.

<b>Development Environment Information</b>
• Development paradigm
• Implementation approach (object-oriented or procedural)
• Simulation development language
• Hardware and platform requirements
• Development and testing tools
• 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 the hot link on [Critical Development Elements and Issues](#). 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***

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.

<b>Information Used in Scoping the V&amp;V Effort</b>
• Results of the problem analysis
• M&S requirements and their associated acceptability criteria
• Results of risk assessment – priorities
• Development profile
• Development environment
• 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, SMEs), and allocating resources. 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.

### ***Identifying Critical V&V Issues***

The critical development elements identified by the M&S PM and Developer are used to identify [critical V&V issues](#), 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 lack of desired data, or the discovery of problems that result in development delays, the V&V schedule and plans have to be modified.

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](#) 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 its 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.

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- **High-risk areas** – As discussed in *Risk Assessment*, 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.

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

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:**

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 scenarios 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 prepare a preliminary cost estimate for the V&V effort independent of preconceived notions of the budget. This estimate can be compared with the allocated budget to determine what trade-offs are justified, or it can be 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.

For an application of tailoring to a V&V effort see [Advanced Topics>Special Topics>Example of Tailoring](#).

**Leveraging** – using the results of work performed by the Developer or during developmental and operational Test and Evaluation 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). 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. 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 separate testing. The M&S PM should review development, testing, and V&V activities to ensure that 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 that the V&V plan focuses on high-risk areas and covers the application needs sufficiently
- **M&S PM** – to ensure that the V&V plan involves a realistic timeline and does not exceed the allocated resources
- **Developer** – to ensure that the V&V effort can provide feedback about development issues in a timely fashion
- **Accreditation Agent** – to ensure that 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. The conceptual model is the bridge between the requirements and the code. It describes the domains of interest and the assumptions upon which the simulation will be built, and it includes all 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.

For more information see [Advanced Topics>Special Topics>Conceptual Model Development and Validation](#).

### **Validate Conceptual Model**

Conceptual model validation involves the following activities:

- 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 that all M&S requirements have been addressed accurately and completely
- Ensuring that each element is defined at a level of fidelity appropriate to the application

The validated conceptual model not only serves as the foundation for the simulation design but also becomes the referent. The M&S PM should allocate resources to the V&V Agent to conduct conceptual model validation and should ensure that 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**

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 model and to assess the appropriateness of the data selections. The M&S PM monitors the V&V tasks involved (see the core document on [Core Documents>New Development>V&V Agent](#) and [Advanced Topics>Special Topics>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 simulation
- 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 design or the 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 and Developmental Testing and Evaluation are a Developer responsibility and should be conducted by the Developer on the basis of a simulation test plan.
- Operational Testing and Operational Test and Evaluation are normally external functions that are the responsibility of the Operational Test Authority. The Operational Test Authority is either established by organizational policy, appointed by the M&S PM, or selected by the User. Operational Test and Evaluation is normally conducted independently and should result in an assessment in accordance with applicable Department of Defense (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 developmental testing (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) to ensure that 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 with validation data that have been either 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 that appropriate SMEs are available for face validation. When operational testing is involved, the M&S PM should encourage the V&V Agent and the Operational Test Authority 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 developmental testing and operational testing (e.g., scenarios, data, tools, measures, metrics) have great commonality with V&V activities: developmental testing is closely related to implementation verification; operational testing 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 that 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 [Resources>Reference Documents>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 on the basis of 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 given 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. The M&S PM provides information regarding schedules, milestones, plans, and products, including any designated reporting formats that the Accreditation Agent should employ. In turn, the M&S PM reviews the accreditation information needs to ensure that 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 selection 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 that allows seamless movement from requirements to conceptual model to design to implementation, it is not impossible.

Requirements Traceability	
<b>M&amp;S Requirements</b>	<ul style="list-style-type: none"><li>• Verified M&amp;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.</li></ul>
<b>Conceptual Model</b>	<ul style="list-style-type: none"><li>• The validated conceptual model establishes the entities, behaviors, and relationships needed in the simulation and is traceable back to the verified M&amp;S requirements.</li></ul>
<b>High-Level Design</b>	<ul style="list-style-type: none"><li>• High-level design transitions the validated conceptual model into system specifications that are traceable back to the validated conceptual model and the M&amp;S requirements.</li></ul>
<b>Detailed Design</b>	<ul style="list-style-type: none"><li>• 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&amp;S requirements.</li></ul>
<b>Code</b>	<ul style="list-style-type: none"><li>• 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&amp;S requirements.</li></ul>

**Example:**

Because of problems with various tools early in Joint Warfare System 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 (designated as the Conceptual Model of the Mission Space in DoD 5000.59-P). 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 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 pre-design products or the design products (i.e., traceability was not possible). To address this problem, the Joint Warfare System 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 if 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.

For more information see [Resources>Reference Documents>V&V Tools](#).

### Information Library

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.

### 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 data 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 on the basis of 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 that the 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 statement of work 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 that appropriate V&V tasks are performed (e.g., M&S requirements verification, planning) in a timely manner. Once the V&V Agent is onboard, 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 that sufficient information is available from the development and V&V efforts to perform a satisfactory accreditation assessment and that 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 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 developmental testing activities (planning, preparation, execution, and reporting) and ensure that the V&V Agent and other interested outside agencies, such as the Operational Test Authority, 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 operational testing, the M&S PM should ensure that the V&V Agent has opportunities to be involved as well. If properly planned and coordinated, the operational testing activities can augment and support the validation effort. See [Resources>Reference Document>T&E and V&V Integration](#) for additional information.

### **Documentation Requirements**

As part of the configuration management process, 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.

M&S VV&A RPG Core Document:  
Program Manager's Role in VV&A of New Development

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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 were 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. Because a Developer may not 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 the development processes (when and how goals were accomplished) and that it articulates the problems and issues uncovered (obstacles encountered and the methods, successful and unsuccessful, used to resolve them).

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

<b>M&amp;S PM Guidelines to Facilitate Documentation</b>
<b>Establish the ground rules.</b>
<ul style="list-style-type: none"><li>• The M&amp;S PM should identify documentation needs in collaboration with the Developer and V&amp;V Agent and establish formats so the artifacts are usable by both current and future users. Encourage the Developer and V&amp;V Agent to be meticulous and prompt in their recording efforts.</li></ul>
<b>Be realistic about the amount to be collected.</b>
<ul style="list-style-type: none"><li>• 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.</li></ul>
<b>Document and collect as it happens.</b>
<ul style="list-style-type: none"><li>• 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.</li></ul>
<b>Be the enforcer.</b>
<ul style="list-style-type: none"><li>• When the stress of impending deadlines sets in, the M&amp;S PM should ensure that the archiving process is not forgotten. The M&amp;S PM is responsible for making sure that things are done right the first time to whatever extent possible.</li></ul>

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 (see [Core Documents>Legacy>Accreditation Agent](#)). 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.

## **Cost Implications and Resourcing**

Costs, of course, are 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 SMEs that may be required to perform specific tasks or provide specific information. As the complexity of the application increases, the need for different kinds of expertise during the V&V effort increases.

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

Sharing tools can both reduce costs and avoid irregularities that arise as a result of tool inconsistencies rather than actual problems with the simulation.

- Computer-aided software engineering tools should support requirements traceability and documentation through all phases of the development process, up to and including archiving.
- 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 convert 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

For more information see [Resources>Reference Documents>V&V Tools](#).

## 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 with the referent. Once the referent is defined, data describing the referent need to be identified and collected or developed. 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.

For additional information on the referent, see the special topics on [Advanced Topics>Special Topics>Developing the Referent](#), [Advanced Topics>Special Topics>Validation](#), and [Advanced Topics>Special Topics>Conceptual Model Development and Validation](#).

## 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

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 with the initial estimates. Detailed monitoring should allow the M&S PM to push the work forward and make midcourse corrections as needed.

## References

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

## Acronyms

CM	Configuration Management
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
T&E	Test and Evaluation
I&T	Implementation and Test
M&S	Modeling and Simulation
PM	Program Manager
RPG	Recommended Practices Guide
SME	Subject Matter Expert
V&V	Verification and Validation
VV&A	Verification, Validation, and Accreditation

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