

Developer'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) Developer's role and interests in the verification, validation, and accreditation (VV&A) of a new simulation. The Developer is responsible for the development of the new simulation. Specific responsibilities include:

- Developing and executing the development plan in coordination with the M&S Program Manager (PM), including identifying the development paradigm, allocating resources, and establishing the schedule
- Defining the simulation domain requirements in coordination with the User
- Identifying and preparing the data needed to both develop and execute the simulation
- Developing the conceptual model based on the requirements of the application
- Designing, implementing, testing, and integrating the software

The Developer is responsible for ensuring that the simulation is built to meet the objectives and requirements of the User and, as such, should be an active participant and supporter of various verification and validation (V&V) activities. The V&V process supports the Developer by helping to reduce development risk and increase credibility. The Roles and Responsibilities discussed in [Key Concepts](#) shows how Developers can assist in some activities, review others, and lead or perform those directly related to development. Developers can also benefit directly from a V&V effort. Results of individual V&V tasks can provide the Developer with timely information regarding issues and problems, allowing them to be resolved before they have a major impact on the development process.

How Does the M&S Developer Impact VV&A?

The Developer should be a major participant in the V&V effort from the beginning of the planning phase until the final piece of evidence is collected for the accreditation decision. The Developer can:

- Coordinate planning to help ensure the individual verification and validation tasks provide timely and meaningful feedback to the development process
- Share information about the development (e.g., serving as a subject matter expert [SME] or point of contact), to help ensure that the V&V Agent has current and accurate information about the development

- Conduct or assist in conducting verification activities in conjunction with software tests
- Coordinate development testing with validation efforts to reduce costs and ensure consistency in the results

Conducting development activities should involve frequent interaction and coordination with both the M&S Program Manager (PM) and the V&V Agent. The Developer should work closely with the M&S PM to coordinate resource requests and allocations to support the program's v&v priorities. The Developer should also work with the V&V Agent to ensure that planned v&v activities help reduce development risk by identifying potential development problems in a timely manner and providing information to support the accreditation decision.

The Developer's impact on the v&v effort is continuous and extensive. The Developer knows how the simulation is being built, controls access to all the simulation development activities and interim products used during the v&v effort, and works directly with the V&V Agent throughout the development process. The Developer should set the tone of this relationship: If the v&v process is recognized as beneficial because it helps reduce risk in the development process, then the Developer is more likely to establish a cooperative relationship. The Developer should help meet the M&S PM's objectives by working with the V&V Agent toward the common goal of developing a simulation that meets the User's needs.

The Developer also has a major impact on the accreditation effort by collecting and saving information throughout the development process. In particular, ensuring the development of artifacts and products that accommodate the needs of the v&v effort can facilitate the accreditation process tremendously.

How Does VV&A Impact the M&S Developer?

A vigorously executed V&V effort can have a major impact on the entire development process. V&V activities can add value to the development that far exceeds the costs involved by:

- Identifying development problems that can be corrected in a timely and economic way
- Collecting evidence regarding the validity and credibility of the simulation
- Providing the information needed to expedite the accreditation assessment

The Developer should work closely with the V&V Agent to ensure that the development is conducted and documented in a way that provides the artifacts, products, and information needed by the V&V effort and to ensure that the V&V effort provides timely information to assist in the development effort. Both of these activities support the M&S PM's and Developer's risk reduction goals.

If a simulation is not subjected to an effective V&V effort during development, the risks are greater that it will not meet the requirements or that additional time, money, and resources will be spent to achieve accreditation. If the V&V effort is conducted post-development, then the V&V activities required to produce the information necessary for the accreditation assessment will be much more extensive and costly. Development tasks may have to be repeated, and problems that could have been detected and corrected easily during the early phases of development have to be addressed after the fact. This can easily cause cost overruns and schedule delays.

Example:

Watts Humphrey of the Software Engineering Institute estimates errors caught during testing and corrected during development may cost as much as 20 programmer hours to fix and 2 to 20 times as much if not caught and fixed until post-development.¹ Davis reports that the later in the development life cycle an error is detected, the more it will cost to repair.² He cites corporate data from General Telephone & Electronics (GTE), TRW, and International Business Machines (IBM) from the mid-1970s, shown in the table below, regarding the relative cost to repair a problem during different phases of development and during use.

Development Phase	Relative Cost to Repair
Requirements definition	0.1–0.2
Design	0.5
Coding	1
Unit testing	2
Acceptance testing	5
Maintenance	20

Proper use of verification and validation for risk reduction supports Developer quality assurance and configuration management actions and provides an additional sanity check. The V&V process helps ensure that the software development process and its artifacts will produce a simulation whose:

- Design is based on well-understood, verified requirements and a validated conceptual model
- Code is based on the verified design that reflects the verified requirements and validated conceptual model
- Results meet the stated requirements and credibly represent the referent

By including the V&V Agent in the process, the Developer can help prevent improper preliminary optimization that may invalidate the work done to validate the conceptual model. This is particularly important in the design and coding of the necessary

representations. For example, military simulations should be based on a validated conceptual model and carefully designed and coded to ensure that the warfighting representations remain valid throughout the process. One of the Developer's greatest challenges is to maintain this validated functionality throughout the development. Finding the balance between the proper level of detail and the proper level of aggregation is difficult in any development. The Developer should ensure that the User, the M&S PM, and the V&V Agent are aware of and concur with development decisions that impact the representations included in the simulation.

Working with the M&S PM and V&V Agent to determine V&V priorities and to plan V&V tasks is a difficult and complex job, particularly when the Developer's priorities are focused on the development of the simulation. However, proper V&V planning and execution can reduce those development risks and help assure accreditation.

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

Developer responsibilities include working and coordinating with the M&S PM and V&V Agent to identify risks and V&V priorities. The Developer should be involved in the selection of the V&V Agent (when permitted under the contractual rules of the development). The Developer should work with the V&V Agent to coordinate plans for the V&V effort and to develop some mechanism to ensure continued coordination throughout the development program.

Typical Developer responsibilities associated with specific V&V tasks are listed in the table below.

V&V Responsibilities of the Developer
• Participate in the development and execution of the V&V plan
• Support event coordination and communication (e.g., notifying the V&V Agent of development reviews and the availability of products required for review)
• Collect and store information
• Coordinate development and V&V activities
• Ensure planning and scheduling are coordinated so the V&V effort can run concurrently
• Participate in the requirements definition to ensure that requirements evolve as needed for the application
• Provide access to data used in the development, testing, and execution of the simulation
• Ensure that M&S development products provide the proper artifacts for the V&V activities
• Work with the V&V Agent to identify required tools and then with the M&S PM to obtain the tools and required training
• Conduct developmental tests and collect verification data

V&V Responsibilities of the Developer (continued)
<ul style="list-style-type: none">• Integrate developmental testing and operational testing with the V&V effort to optimize resources
<ul style="list-style-type: none">• Be prepared to work with the M&S PM and the V&V Agent to make tradeoffs between development resources and V&V resources
<ul style="list-style-type: none">• Ensure that V&V reports are reviewed by participants in a timely manner
<ul style="list-style-type: none">• Establish procedures for correcting problems identified by the V&V process in a timely manner
<ul style="list-style-type: none">• Provide support as required for the accreditation assessment

Mechanisms the Developer can use in meeting these responsibilities are listed below and discussed in the following paragraphs.

Coordinate Activities

The Developer should not assume that the V&V Agent can conduct the planned activities without significant support and frequent updates from the development team. Left alone, the V&V Agent may not be aware of changes in the software development process, schedule modifications, or revised requirements and will be unable to provide timely warnings of problems. In order to gain value from the V&V process and improve the likelihood of accreditation, the Developer should work with and assist the V&V Agent continuously to:

- Coordinate V&V resource requests with the M&S PM
- Devote allocated resources to V&V and V&V support
- Identify technical risk and management risk areas for V&V attention
- Ensure the availability of development products and information necessary to conduct the planned verification and validation tasks
- Take advantage of the V&V results to improve the software development process and reduce program risks
- Support efforts to coordinate test and evaluation (T&E) and V&V activities

Failure to become involved early in the V&V process and failure to address the V&V Agent's needs may result in the Developer being tasked to produce necessary artifacts or products that were not planned for and expending resources to support the V&V effort.

Coordinate Plans

When possible, the V&V plan and development plan should be developed at the same time to coordinate activities and schedules. The paradigm selected for the development

process and the scheduling of development milestones have a direct impact on the V&V effort, and V&V planning should take them into consideration. Individual V&V activities should be scheduled so that problems uncovered can be reported and responded to in a timely manner. The development plan should also include some flexibility for addressing problems identified. The Developer should review the V&V plan to verify the schedules and to ensure that the development products required by the V&V plan are defined in the development plan.

Both plans should include a schedule of joint reviews at each stage of the development effort when V&V results are reviewed and the identified errors and problems are addressed. The results of V&V activities should be incorporated into the development as soon as possible to reduce redesign and reprogramming costs and minimize the impact on the development schedule.

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

Establish a Point of Contact

Designating a single development point of contact to work with the V&V Agent should help reduce potential miscommunications and unnecessary interruptions. The point of contact would be responsible for:

- Coordinating interactions and providing access to development artifacts and products
- Participating in the development of the V&V plan to ensure that it is executable and is tailored to address both the concerns of the development and the needs of the application
- Ensuring that relationships and responsibilities are well defined and well understood by all participants (e.g., M&S PM, V&V Agent, Accreditation Agent, Developer, User, SMEs)

Establish Oversight Groups and Integrated Product Teams

To achieve greater participation in the V&V process, the Developer or M&S PM can organize an oversight group made up of representatives from all aspects of the program. An oversight group can help prepare plans, review V&V reports, and recommend changes to address the problems identified. An oversight group can also monitor and support specific activities, such as requirements definition, simulation development (including integration), resources, and risk reduction. The oversight group should ensure that the planned V&V process supports good software engineering practices. Although the M&S PM would normally be responsible for forming and heading an oversight group, the Developer can initiate the action and can either serve as or designate a chair to manage the group.

The responsibilities of an oversight group should expand and change as the development program progresses. A successful oversight group can evolve into an integrated product team.

Example:

Immediately after the Joint Warfare System V&V contract was awarded, a V&V Oversight Group was established. Led by the V&V Agent, the Oversight Group included representatives from the program office (the designated point of contact, a software engineer, and a systems engineer), the Defense Modeling and Simulation VV&A Technical Working Group, the Joint Staff, the Service analysis agencies, as well as from Joint Data Support (the organization responsible for providing input data) and V&V experts from other organizations. The Oversight group helped develop both the V&V process and the ensuing plan and then evolved into the V&V Working Group. After the Joint Analytic Modeling Improvement Program Steering Committee directed integration of the V&V and T&E efforts, the working group evolved into the V&V-T&E Integrated Product Team.

The Integrated Product Team process (such as the working-level Integrated Product Team process described in Department of Defense [DoD] 5000.2-R) is a good way to coordinate the V&V effort with other interested organizations involved in the simulation development. More stringent and complex integrated product team organizations are also possible.

Example:

A mission training simulation may also be a major program acquisition requiring multiple integrated product teams for development of hardware, software, and courseware.

In the Joint Warfare System program, a hierarchy of oversight groups was established. The lowest tier is the V&V-T&E Working Integrated Product Team, which addressed V&V and T&E issues at the action officer level; the middle tier is the Joint Analytic Model Improvement Program Steering Committee, which focused on major issues, including V&V issues that could not be resolved in the working integrated product team; and the upper tier is the Joint Analytic Model Improvement Program Executive Committee.

When multiple or tiered integrated product teams are involved, a separate primary Developer may be responsible for each of these, or one Developer may be responsible for multiple integrated product teams. Multiple integrated product teams may be integrated using a Systems Engineering and Integration Team or similar group.

Employing an integrated product team can be an effective way to improve communications throughout the simulation development process. The integrated product team participants should maintain awareness throughout the development effort, monitoring the progress of the development and V&V efforts, reviewing the results of V&V activities, and working together to resolve issues in a timely manner.

Establish a Review Process

The development schedule should include time at each phase for review of and response to the V&V results of that phase. Frequent communication with the V&V Agent throughout the development process is very important. The V&V Agent should be kept informed of changes in the development process, products (including content and format), and schedule. Products should be made available for review in a timely manner to ensure that results of all verification and validation activities are adjudicated properly.

By reviewing V&V reports as they occur, the Developer should be able to make timely corrections to the developing simulation. In addition, prompt reviews ensure that the V&V activities are on track. Regardless of how conscientiously communication is maintained, the V&V Agent may base the analysis on incorrect assumptions or outdated information. A judicious review of the V&V reports by all interested parties may identify the factual misconceptions that led to faulty analysis. The purpose of such a review is to identify errors due to incomplete or incorrect information and provide an opportunity for rebuttal and discussion. Both the V&V Agent and the Developer should be provided the opportunity to correct errors before the V&V reports of each phase are delivered to the User through the M&S PM.

Example:

If the Developer changes something during the design phase that isn't completely reported to the V&V Agent, design verification will proceed on the basis of incorrect assumptions about the design and may return an unfavorable or incorrect preliminary design verification report. By reviewing this report before it is forwarded to the M&S PM, the misunderstanding can be identified and the design verification redone on the basis of accurate information.

This process allows minor problems and misunderstandings to be corrected in a timely and economical way and allows the M&S PM and User to focus on serious problems.

Apply Configuration Management

The Developer should support the M&S PM's configuration management program by maintaining records, producing the required products, and coordinating with the V&V Agent to assess the impact of changes made in the development of previously verified or validated products.

Example:

If an attrition algorithm uses weather and terrain characteristics and data values are not available for the location or environmental conditions in the intended scenario, then a decision must be made to either change the algorithm, modify the scenario, or use substitute data. This decision can impact aspects of all preceding development phases including the requirements and acceptability criteria associated with attrition, the conceptual model, the interactions between algorithms, and the design. In each case, those aspects of the development that have already undergone verification or validation should be reexamined to determine if the decision will impact their respective acceptability.

Any change made during development should be subject to V&V review to ensure that previous V&V assessments remain accurate. Changes made in the conceptual model, design, or code may invalidate previous assessments of their validity or verification status.

Configuration management of a new development should include a process for standardization and control of development products and their associated archives. The Developer's configuration control process, often based on a developer configuration control board or similar oversight group, should provide a process for reviewing changes to the simulation during development. Before any changes are made, they should be documented (e.g., using Internal Change Request forms) and submitted for approval by the oversight group. Both the V&V Agent and Accreditation Agent should participate in this oversight group.

The complexity of a configuration management process is connected to the development paradigm selected. The products from a more structured paradigm (e.g., waterfall) are more easily tracked than those from an iterative paradigm (e.g., spiral, incremental). Similarly, the artifacts and products from a more structured paradigm tend to be more mature. All aspects of the development and testing should be documented and saved at least until either the simulation is no longer used or new documents describing modifications have replaced the originals. Throughout the development process, all information concerning the development including products, tests, and changes should be properly captured for use during the V&V process and the accreditation assessment. Once the accreditation decision is made, this information should be turned over to the M&S PM to be archived.

It is useful to retain and archive all raw data supporting the formal reports and other products of the development, especially if the simulation is expected to enjoy considerable reuse. Significant resources (e.g., time) could be saved in a future V&V effort by reviewing the documentation and even using old data to investigate slightly different parameters. Using current technology raw test and analysis data can be collected in quantities to satisfy even the most avid analyst. The Developer should support such activities for them to succeed.

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

The Developer faces a number of challenges in support of the V&V effort. These are listed below and discussed in the following paragraphs.

Managing Resources

In most M&S development programs, the M&S PM allocates development and V&V funds separately. However, the Developer does need to ensure that the development resource requirements include resources to support the V&V effort. This support may take the form of testing, documentation, making personnel and equipment available, and training. These resources should be identified and allocated as early as possible so that tradeoffs do not need to be made later on during the development process. Early

development of a detailed V&V plan and its careful integration with the development and testing plans are necessary to identify realistic resource needs and to determine appropriate resource allocations.

Adequate Definition of the Objectives and Requirements

In order to establish appropriate development and V&V priorities, the Developer needs:

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

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

Formalized Development Products

Traditional simulation development begins with 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

In particular, documentation of the conceptual model is essential because it 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. However, some simulation development efforts do not include a deliverable called "conceptual model"; and, while the information provided by a conceptual model exists in various pieces (e.g., requirements documents, simulation specifications, design products), it may not be readily and credibly identified as such. In these instances, the Developer should work closely with the V&V Agent and User to ensure they all participants understand how the simulation is being developed and what products are being created that can provide the information normally embedded in the conceptual model.

Example:

Because the Joint Warfare System program does not have one development product that includes all of the elements traditionally contained in a conceptual model, the V&V Agent was required to gather multiple development artifacts and deliverables and piece together the necessary elements to produce a "surrogate" 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, there is no traceability between the requirements and the code, and inconsistencies between the requirements and the Developer's concept may not be identified until later in the development. Then the Developer may need to spend additional time, effort, and resources reworking the simulation design and/or implementation.

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

Timely Communication

Information should be shared in a timely manner so potential problems can be identified and corrections made before the development is so far advanced that corrections can't be easily or economically made. A Developer may become so heavily focused on meeting the development schedule and addressing development challenges that problems are ignored until they become both costly and cumbersome to correct. By appointing a dedicated point of contact to monitor the V&V process or by participating in oversight groups or integrated product teams, the Developer can help ensure that V&V activities are accorded proper support and prompt attention. The Developer should also ensure that the development schedule allows sufficient time for V&V tasks to be completed, problems identified, and changes made before proceeding to the next phase in the development.

Data

A major difficulty in the development of any new simulation is obtaining appropriate, accurate, and authoritative data. A large variety of input data is required to execute a simulation. Data (e.g., surrogate data, validation data, test data) are needed to test and validate the various components of the simulation. In addition, simulation results (output data) are essential to the User.

The Developer has the responsibility for defining data needs for both simulation development and execution. Once the Developer has identified the data needed, the User and M&S PM are instrumental in identifying and obtaining the required data from authoritative sources. The Developer also needs to ensure that the simulation can provide the output data necessary to meet the needs of the Users and those involved in

testing and validation. The Developer is then responsible for transforming, assimilating, and managing these data.

For more information see [Resources>Reference Documents>M&S Data Concepts and Terms](#).

Data Security

One of the major challenges associated with data is protecting data values from accidental or intentional contamination, mishandling, or misuse. In addition, the security classification involved (e.g., Secret, Top Secret) restricts access to and usage of the data to only those participants in the development, testing, and V&V efforts with appropriate clearances. The Developer needs to ensure that data integrity is safeguarded by providing physical security to protect the data from use by unauthorized personnel and by providing alternative or surrogate data that can be used by all participants.

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.

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 actual and surrogate, for the intended use.

Data Collection

Another challenge associated with data is determining what data should be collected and how. The Developer should determine what output data are needed on the basis of the requirements, metrics, and acceptability criteria, and should establish a process for output data collection and storage. Concurrently, the V&V Agent should develop a process for tracking and validating output data.

The Developer should ensure that the User and the M&S PM are made aware of data needs (both the data needed for the development effort and the data needed to run the simulation). The Developer should provide information on data quality assurance efforts completed by the data providers and any data problems that may affect simulation development or execution to the V&V Agent who, in turn, should provide the Developer with information about the accuracy, fidelity, and sufficiency of the data.

Coordinating the Testing Effort

Testing is a major method employed in simulation development and in V&V to assess correctness. Two basic types of testing are normally involved in simulation development:

- Developmental testing and Developmental T&E are Developer responsibilities and should be conducted by the Developer on the basis of a simulation developmental testing or Developmental T&E plan.
- Operational testing and Operational T&E are normally external functions that are the responsibilities 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 T&E is normally conducted independently and should result in an assessment in accordance with applicable DoD regulations.

To a large extent, many aspects of both developmental testing and operational testing have great commonality with V&V activities (e.g., scenarios, data, tools, metrics). Testing and V&V tasks should be coordinated to reduce excessive or repetitive testing and to synergize the overall effort. By coordinating testing and V&V plans, necessary verification tasks that can be done in conjunction with testing activities can be included in the testing program, and testing activities (e.g., unit testing and integration testing) can be structured to support results validation.

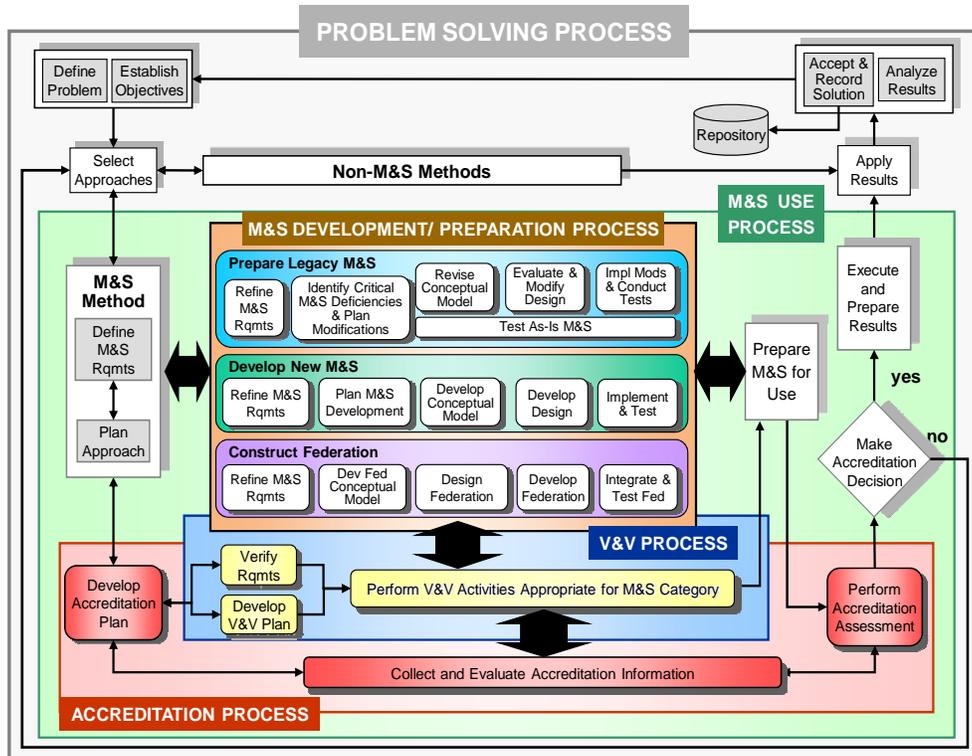
The Developer is responsible for all developmental testing activities (planning, preparation, execution, and reporting) and should ensure that the V&V Agent and other interested outside agencies, such as the Operational Test Authority, are included in the testing process. The V&V Agent should be allowed to review test plans, participate in the actual testing, and review the results. In some development paradigms it is possible (and preferred) to conduct most of the implementation verification tasks in conjunction with developmental testing. Identifying and exploiting these opportunities should be a key part of V&V planning and Developer–V&V Agent coordination. During operational testing, the V&V Agent should be involved in the planning and test report review process. If properly planned and coordinated, the operational testing activities can augment and support the validation effort.

For more information see [Resources>Reference Documents>T&E and V&V Integration](#).

Role of the Developer in the Overall Problem Solving Process

Problem Solving Process

The diagram below shows how the M&S life cycle fits into the overall problem solving process. This diagram depicts the relationships among 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 complete that process.

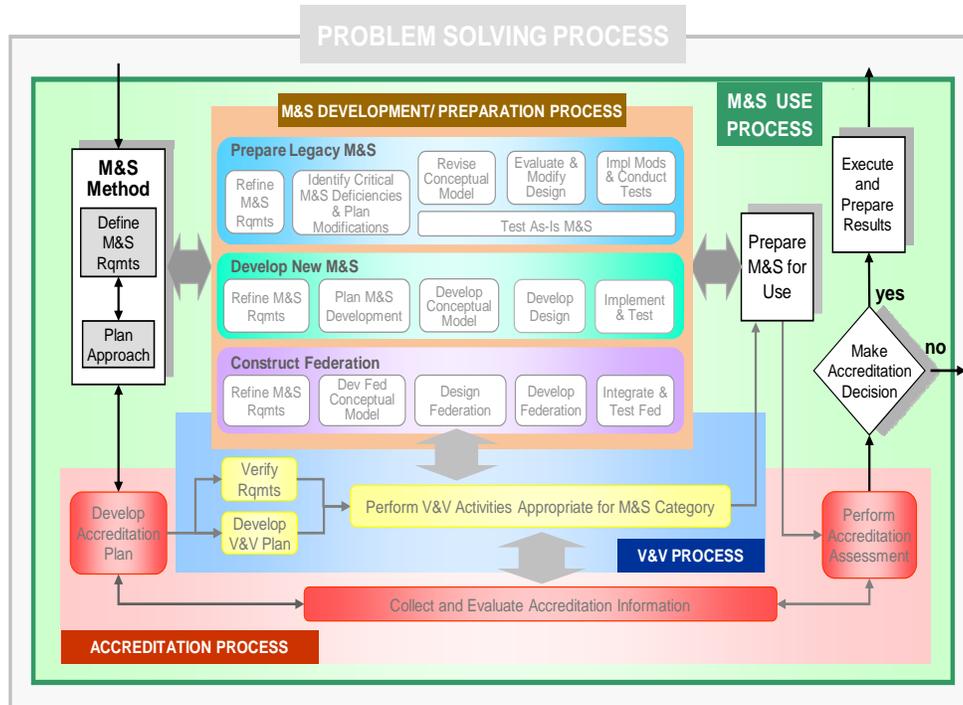


The Overall Problem Solving Process

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 completes 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 **M&S Use Process**, the first nested process in the **Problem Solving Process**, begins, as shown in the following figure.



M&S Use Process in the Problem Solving Process

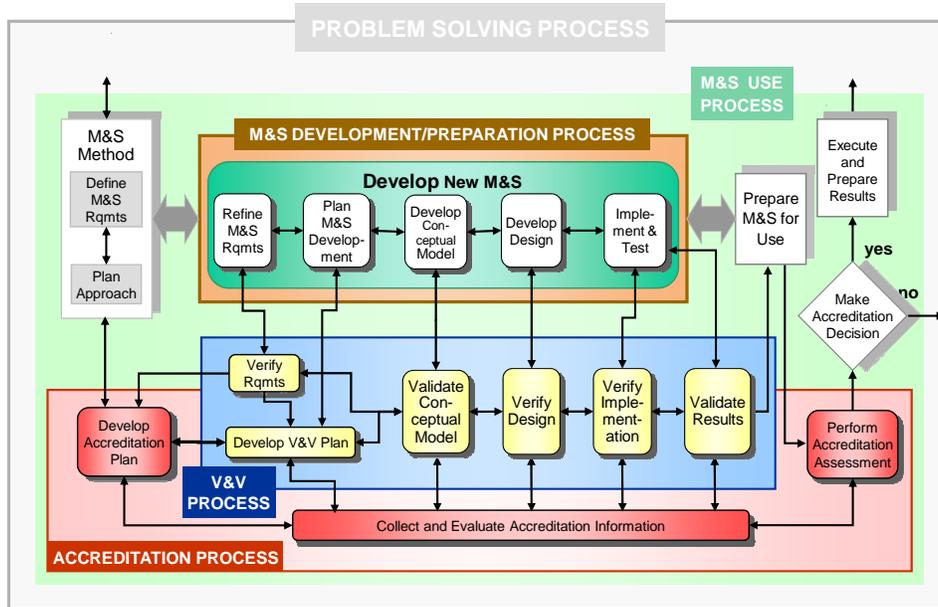
At the beginning of this process, during the **M&S Methods** phase, the User designates the M&S PM and Accreditation Agent, who support the User in:

- Defining M&S requirements and their associated metrics and acceptability criteria
- Identifying and assessing risks
- Establishing priorities
- Establishing contractual agreements
- Planning the overall approach

M&S Development/Preparation Process

The next nested process, **M&S Development/Preparation Process**, begins when the M&S PM designates the Developer. The M&S PM and Developer define the development profile, select the development paradigm, establish the development schedule, and initiate the development plan. The Developer is responsible for carrying out the plan.

Regardless of which development paradigm is followed, the development process for new simulations, **Develop New M&S**, consists of the five basic phases shown in the following New M&S Development Process figure.



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

Associated with each development phase is a corresponding activity in the V&V process 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 V&V activity involves a number of tasks in which the Developer can participate. The Developer's role in these V&V activities and the associated accreditation process is discussed in the following section.

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

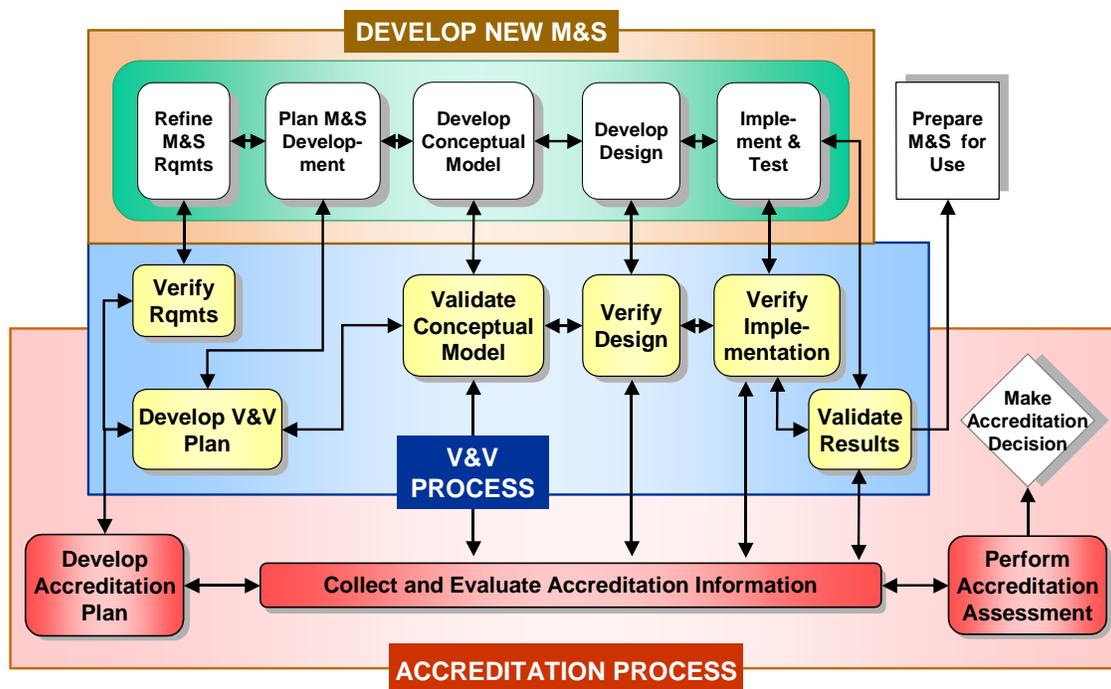
Overview

The Developer is responsible for ensuring that the simulation is built to meet the objectives and requirements of the User and as such should be an active participant and supporter of various V&V activities. The Developer should support the V&V effort by providing the information needed for the specific verification and validation tasks, by performing verification tasks in conjunction with development activities (including testing), and by modifying the simulation in response to the results of a V&V activity. The Developer should review authoritative VV&A references, guidance documents, and policies to learn about the V&V process, accreditation, and the various activities involved.

A Developer should work to instill in the development team a positive attitude about the V&V process by:

- Working with the M&S PM and V&V Agent to identify priorities and integrate them into the development plan
- Promoting an atmosphere of cooperation from the very beginning
- Encouraging frequent and open meetings to discuss issues
- Establishing a process to respond to problems identified by the V&V effort and make changes where needed
- Providing evidence that the findings of the various V&V activities and subsequent changes made are helping produce a better product in a timely and economical fashion

The figure below shows the relationships and interactions between the new M&S development process and the V&V and accreditation processes.



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Within each development phase, the Developer conducts activities that particularly impact the V&V effort. In addition, associated with each phase is a corresponding V&V

activity that includes a number of tasks in which the Developer can play a role. These phases are listed below and discussed in the following paragraphs.

Refine M&S Requirements Phase

Refining M&S Requirements

M&S requirements are those requirements that the simulation must meet to serve a particular purpose. They include all the requirements from the user and problem domains of the specified application and the requirements from the simulation domain (e.g., operating requirements) that are derived from them. The User is responsible for defining the user and problem domain requirements; the Developer should work with the M&S PM to define simulation domain requirements on the basis of the needs of the application and ensure that they are verified. Because requirements are often enhanced, clarified, or refined during the development process, the Developer should support additional verification activities to evaluate them in a timely manner.

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

Verifying M&S Requirements

Requirements verification should be conducted to ensure that the M&S requirements fully address the User's requirements; and it should be conducted as soon as possible after requirements definition. (If a V&V Agent has not yet been selected, then the User should select SMEs to help with this task.) The Developer should monitor or participate in this activity to ensure complete understanding of the requirements. Requirements verification should be revisited whenever the decision is made to change or modify requirements.

Plan M&S Development Phase

Planning M&S Development

After the M&S requirements have been refined and verified, the actual development process begins. The Developer should work with the M&S PM to select the development paradigm to be used to guide both the development and the V&V efforts, to scope the development, and to develop the plan. The basic plan should identify, schedule, and allocate resources for specific development activities and designate exit criteria for each phase of the development. Major considerations include both development and operational risk. When the M&S Development plan is complete, it should be the basis for the development of the V&V plan.

For additional information see [Core Documents>New Development>M&S Program Manager](#), [Advanced Topics>Special Topics>Paradigms for M&S Development](#), and [Advanced Topics>Special Topics>Risk and Its Impact on VV&A](#).

Developing the V&V Plan and Developing the Accreditation Plan

During the development of V&V and Accreditation plans, the Developer should provide support and information. By providing information about the details of the development plan, the Developer can ensure that the V&V and Accreditation agents have sufficient knowledge to prepare V&V and accreditation plans. The Developer should assist in the development of the V&V plan by identifying development resources that can be leveraged and tools that can be shared, and by providing information regarding planned development activities and products. The Developer can also help schedule events and activities, define criteria for evaluating and exiting each development phase, and identify information to be collected for the accreditation assessment.

The Developer and M&S PM should coordinate with the V&V Agent in the development of the V&V plan to ensure that the tasks involved address the requirements, are scheduled to be conducted in a timely manner, and can provide meaningful results. One of the important items that should be included in this plan is a method for resolution of disputes between the V&V Agent and the Developer.

Throughout the planning process there should be a continuous review to identify opportunities to coordinate the development and V&V processes, share information, maximize resources, and minimize duplication.

Develop Conceptual Model Phase

Developing the Conceptual Model

The conceptual model serves as a vehicle to move from the requirements to design and code. It functions as a blueprint by which the Developer and others can understand precisely what needs to be built. The Developer should work with the User to develop the conceptual model and document the important features of the simulation being built (e.g., objects, elements, scenarios, representations, behaviors, functions, data, fidelity).

In some efforts, the conceptual model takes on different forms as a result of the development paradigm selected, resource and time constraints, and background of those involved. For example, in object-oriented development, use cases have been used as the mechanism to move from requirements to design thereby bypassing a more formal conceptual model.³ Another alternative or surrogate conceptual model can be made by starting with one or more of the user manuals and adding attachments containing the traditional conceptual model elements. When a surrogate conceptual model is used, the Developer should provide details on its structure to the V&V Agent to assist in validation. Regardless of what form the conceptual model takes, the information contained in it should be sufficient to support follow-on development phases and VV&A activities.

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

Data Acquisition and Preparation

During the development of the conceptual model, the lengthy process of data acquisition and preparation should also be initiated. The Developer should coordinate with the M&S PM to ensure that sufficient resources are available to obtain data, to support data V&V activities, and to ensure that those involved with preparing, verifying, or validating the data have ample access to the data and model when required.

In addition to the data intended for use in the simulation, the Developer should also expressly identify **surrogate data** to be used during the development effort. Surrogate data are used to test aspects of the simulation when the actual data intended for use in the simulation cannot be used (e.g., when classified data are needed for the application but the simulation is being developed in an unclassified environment). Data V&V should be conducted to ensure that surrogate data are appropriate substitutes; and, as the development process continues, surrogate data should be replaced with the actual data before testing is completed.

Data V&V

The data V&V effort begins with the verification of data needs identified in the conceptual model and the verification of candidate data sources identified by the Developer and User. Candidate data sources are checked to determine their authority and the availability of their data. Metadata (data describing the data) are reviewed to determine the quality of the data and their fitness for the intended use. Once data have been acquired and prepared for use (e.g., transformed, aggregated), they are validated to ensure that they result in accurate and appropriate outputs when used as intended in the simulation.

The data V&V effort continues as an integral part of the V&V process throughout the remainder of the development as additional data sources are selected and data are prepared for use. The Developer can use the results of each activity to assist in the final selection and preparation of data to use in the simulation.

Additional information is available in [Advanced Topics>Special Topics>Data V&V for New Simulations](#) and [Resources>Templates>Data Quality Templates](#).

Validating the Conceptual Model

Conceptual model validation determines if the Developer's concept of how the simulation should be designed and developed is sufficient to meet the needs of the application. It identifies inconsistencies in the intended interactions, problems with fidelity, incompatibilities among requirements, and missing or misinterpreted requirements. Conceptual model validation ensures that there is a credible basis for the development effort.

The Developer should have a procedure in place for obtaining and addressing recommendations resulting from the conceptual model validation and for submitting the modified conceptual model for reassessment. When the conceptual model validation

reveals serious problems that impact the overall development program, the Developer should work with the M&S PM to determine program risk. The M&S PM, in turn, should consult the User when resolution of the problem may impact the success of the program.

If the conceptual model is not identified as a formal development product (or contractual deliverable), the Developer should be prepared to work with the V&V Agent to identify the different products that can be grouped to create a surrogate conceptual model. Validation of a surrogate conceptual model is complex, because it entails validating each component separately and then validating the integrated surrogate. However, validation of a surrogate conceptual model is critical; it provides evidence that the Developer's vision is credible, sufficient, and complete. When dealing with a surrogate conceptual model, the V&V Agent may need additional time and assistance developing a validation plan as well as additional assistance identifying, collecting, and explaining the various pieces of information involved.

Develop Design Phase

Developing the Design

During the design phase, the Developer translates the capabilities derived from the requirements, architectural representations, algorithms, behaviors, interactions, data needs, constraints, and limitations defined and described in the validated conceptual model 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 (process-oriented or object-oriented). Together these factors determine when specific information is available, what levels of maturity various products attain, and how and when resources will be used.

Verifying the Design

Design verification confirms that each design iteration is based on the validated conceptual model and that the requirements are properly represented. It is repeated for each iteration of the design. The basis of design verification is requirements tracing, which also provides a way for the Developer to ensure that the requirements are correctly implemented.

The Developer is responsible for ensuring that each requirement can be traced through the design and implementation to the smallest element of software (e.g., a subroutine or function) that supports its implementation. In addition, the trace should point to the test cases or other verification methods used to assure that the requirement is appropriately satisfied in the software.

This information is readily documented in a matrix, which can be constructed using a spreadsheet, database management system, or specially designed tool. When

specialized test cases and other V&V techniques, both planned and applied, are added, the requirements traceability matrix can serve as a blueprint for the V&V program as well. The joint development and maintenance of the requirements traceability matrix is an excellent example of how a single tool can readily serve both software development and the M&S VV&A intended uses.

The Developer should either establish a requirements tracing process or employ requirements tracing tools to ensure that this activity is performed consistently and completely. Both the preliminary (or high-level) design and the detailed design are verified to ensure they are based on the validated conceptual model. The Developer should have a process in place for receiving the results of each design verification activity and resolving the issues identified.

Each problem should be adjudicated and the Developer (unless the User or M&S PM or other authority has asked to be included in this process) should decide whether or not to make design changes. The decision should be based on the impact of the problem on the credibility of the resulting simulation, the costs of correcting it, and the risk of producing a simulation that does not meet the requirements. Changes made during the design stage tend to be less expensive, in terms of time and resources, than those made during or after the design has been implemented in code. However, if the decision is made not to modify the design, the issues raised remain in the design verification report and the Developer should expect to provide a rationale for this decision.

Implement and Test Phase

Implementation and Testing

During this phase, the Developer realizes the M&S design in hardware and software. Both types of components are constructed, tested, and integrated, and the actual data and databases are installed and tested.

Verifying Implementation

Code or implementation verification is frequently done by the Developer as part of a standard quality assurance program. However, the V&V plan should identify the implementation verification tasks needed to address the requirements of the application, regardless of who performs them, and the Developer should ensure that the quality assurance program accommodates the V&V plan. The V&V Agent should monitor or assist with the Developer's code verification and review the resulting reports. When custom hardware is involved, the scope of the verification effort can grow significantly to include review and assessment of the hardware fabrication and integration. Close coordination and cooperation are required to ensure that the V&V Agent understands the methods employed, the problems identified, and the corrections made. Results should be recorded by both the Developer and the V&V Agent.

As the pieces of the code or sections of the simulation are verified, they are also tested and validated. During unit and integration testing, the Developer should work with the

V&V Agent to provide information and assistance as needed. It is recommended that the Developer have a procedure in place for addressing and resolving problems identified during these activities.

Validating Results

Results validation examines the execution of the simulation and data in its entirety. It is conducted to determine how realistic the M&S outputs are under conditions that are determined by the application (i.e., how closely the simulation results match the referent). The validation effort should be performed through comprehensive iterative testing and assessment of all the functionality to ensure that everything is working correctly. However, the specific tasks involved are highly dependent upon the type of simulation and its intended use. As a general rule, discrete pieces of the simulation (both algorithms and data) are first validated separately to determine if they adequately perform their functions and then are integrated incrementally and tested in combination. Additional information on results validation is available in [Advanced Topics>Special Topics>Validation](#).

The Developer should ensure that the V&V Agent has access to the simulation and facilities to conduct the validation. Also, the Developer should ensure that the V&V Agent has access to the results of any testing (e.g., developmental testing) that has been conducted. If operational testing is involved, the Developer should encourage the V&V Agent to work with and cooperate with this process to maximize resources. Integrating results validation with the concurrent operational testing activity can greatly reduce the impact on resources.

Example:

In Joint Warfare System, the results validation process includes:

- 1) Analysis of the required output for analysis based on the Measures of Effectiveness identified in the Operational Requirements Document; creation of a complete set of model validation criteria for the Measures of Effectiveness
- 2) Mapping of the measure of Effectiveness to the Joint Warfare System Study Team's Joint Warfare System Metrics (actually an aggregated and rolled up set of the measures of effectiveness in more "analyst familiar" terms by a group of future users)
- 3) Mapping of the metrics to the Joint Warfare System Study Team Report set
- 4) Identification of simulation output and the variables that could be changed to affect that output
- 5) A base case run and multiple excursions to provide output for sensitivity analysis

Results are presented in a Joint Warfare System Revalidation Report that is reviewed by the Joint Warfare System Office and the Joint Warfare System V&V-T&E Working Integrated Product Team prior to inclusion in the Joint Warfare System V&V reports for presentation to the Joint Analytic Model Improvement Program Steering Committee.

Prepare M&S for Use Phase

Preparing M&S for Use

Once the individual components of the simulation have been verified and tested, the Developer should prepare the simulation to be tested in its entirety, including all data, scenarios, etc. that will be involved in the actual application. The Developer should prepare and execute the simulation to provide base case and excursion information. Alternatively, the Developer should prepare the simulation for execution and provide it to the V&V Agent (and/or operational testers) for execution.

Performing the Accreditation Assessment

The accreditation assessment process should be conducted throughout the development process. The Developer should be prepared to provide support upon request (e.g., information, products). Ideally, the Developer participated in the development of the acceptability criteria that serve as the basis for the accreditation assessment and the V&V effort is sufficiently robust to provide all the information needed. However, if the Accreditation Agent determines that the evidence that has been collected is insufficient, then the Developer may need to coordinate with the V&V Agent to provide additional information and be prepared to configure and execute the simulation to address the insufficiencies.

Additional Major Considerations

Software and V&V 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 Developer should work with the M&S PM and V&V Agent to obtain tools that are suitable for both simulation development and verification and validation activities. 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.

Example:

Both design tools and coding environments should support requirements traceability. Requirements should be assigned unique identifiers that can be used by design and coding tools to trace requirements.

Traceability is a critical feature for software and V&V tools. The ability both to trace and to verify the traceability of requirements to the conceptual model and to system and subsystem specifications and then to confirm that design and code meet the requirements through validation significantly reduces redo costs during hardware/software integration and initial operational T&E.

The Developer should plan to use both tools and data systems that support archiving and should try to ensure that these tools are made available for use in the V&V effort.

Example:

The V&V Agent was unable to use the Joint Warfare System computer-aided software engineering tool products for tracing requirements or other V&V tasks because the tool was not designed to provide this sort of linkage. 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, the *DoD M&S Master Plan*). However, the flow chart diagrams were standalone products 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. As a result of this problem, the requirements could not be consistently linked to either the predesign products or the design products. 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. Identification of this problem by the V&V effort was one of the reasons the change was made.

Joint Warfare System used the Enterprise Model and Joint Advanced Distributed Simulation (JADS) to obtain SME knowledge and concurrence for their development process. Initial formatting problems and content inconsistencies in the JADS that were identified during the V&V effort resulted in changes in the Joint Application Design product. The V&V Agent identified inconsistencies in the SME review process for each Joint Application Design that prompted changes, which resulted in better SME validation and better capture of warfare functionality in the simulation.

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

Security

Although security is primarily the M&S PM's responsibility, the Developer should ensure that the development effort is organized to accommodate proper security measures:

- 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 lockup, need-to-know information sharing).

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 classifications, representing an additional challenge for partitioning the development

effort and for coordinating testing and V&V activities. The Developer should attempt to keep the simulation and the elements of the simulation unclassified for as long as possible. However, when this isn't possible, a system of working with classified information for V&V should be established. The Developer should ensure that those participating in the V&V effort have the required clearances to gain access to the simulation.

Example:

The Joint Warfare System simulation was developed in a secure classified environment. Although most of the warfare descriptions, algorithms, and code were unclassified, there was enough classified information in the scenarios and data to require that all Joint Warfare System information be classified. When unclassified information could not be obtained for the validation effort, the Developer provided access to the Secret Internet Protocol Router Network for the V&V Agent to make classified artifacts available to the User community for the validation effort.

Developer's Relationship with Other Roles

Developer's Relationship with the User

Although the Developer typically has little direct contact with the User in an official capacity (information is normally exchanged through the M&S PM), all information concerning the development program should be made available upon request. Frequent interaction between the Developer and User should increase the likelihood that the simulation is being built to the right requirements.

In large, multipurpose development programs, a user group may be formed that includes all potential Users (or their representatives) to ensure that all information regarding the development process and the V&V effort is available. Members of the user group may serve as SMEs during requirements definition and verification, conceptual model development and validation, and results validation.

Employing user groups during the development process allows future potential Users to become aware of how the simulation is being built, what capabilities and limitations are involved, what activities are undertaken to assess the simulation's credibility, and what risks are involved in using it in a given application. Early and frequent User involvement in testing is another excellent method to reduce development risk. However, the Developer should ask the M&S PM for adequate resources to support the necessary training and access to the simulation during development. The Developer should also encourage the V&V Agent to take advantage of any early User testing to augment the verification and/or validation process.

Developer's Relationship with the M&S Program Manager

The M&S PM is normally responsible for designating the Developer, allocating resources to the development effort, establishing exit criteria for each phase in the

development process, and assessing risks involved. The Developer and M&S PM should meet frequently to discuss the status of the development effort in terms of the results of V&V activities. The M&S PM makes decisions (e.g., priorities, tradeoffs, development modifications) during the development program on the basis of V&V results and User guidance, and the Developer implements them.

Developer's Relationship with the V&V Agent

The Developer and V&V Agent should work together as a team. The Developer has full control of the form and content of the development products and of the schedule of development events that impact the activities and schedules of the V&V and accreditation assessment processes. The Developer should share as much information (e.g., M&S requirements, conceptual model, evolving designs, code, instance data, testing plans and results) as possible with the V&V Agent throughout the development process to ensure that V&V activities are conducted in a timely manner. 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).

The Developer should also support the V&V effort by:

- Providing prompt and positive responses to issues resulting from V&V activities
- Helping develop and execute the V&V plan
- Participating in reviews
- Sharing resources (e.g., tools, personnel, data)
- Providing training on shared tools and equipment and model execution
- Establishing and maintaining a constructive, cooperative atmosphere

The V&V Agent should support the Developer by:

- Sharing the results of each V&V task promptly
- Offering recommendations for problems
- Responding to Developer needs (e.g., reevaluation of modified components)
- Establishing and maintaining a constructive, cooperative atmosphere

Developer's Relationship with the Accreditation Agent

The Developer should provide support to the Accreditation Agent as needed. Normally, the Developer supports the Accreditation Agent indirectly through the information provided for the V&V effort. However, in some instances, such as when the V&V results

are ambiguous or identify new issues, additional information may be needed. In addition, in situations where the Accreditation Agent is not designated until after the development and V&V plans have been set in motion, the Developer should collect as much information as possible throughout the development process to ensure that it will be available if needed. In all cases, the Developer should work with the Accreditation Agent to develop the Acceptability Criteria for use in the Accreditation process.

Developer's Relationship with Others

Operational Test Authority

The Developer should work with any external test agencies (e.g., Operational Test Authority) that have been selected to participate in the M&S program. The participating test agencies should be included in any assessment groups (integrated product teams or working groups) that address V&V activities. When possible, the Developer should organize activities to allow coordination between the V&V Agent and testers to reduce the resources and time needed to obtain the necessary information.

Documentation Requirements

Unlike the User, who has a vested interest in being able to reuse a simulation, and the V&V Agent, who recognizes the importance of accurate and complete information in establishing credibility, the Developer may not collect and save documentation beyond what is specified in the contract (e.g., conceptual model, design specifications, final reports, user manuals). Therefore, it is important that the contract contain product specifications to ensure that information supporting the V&V effort and the accreditation assessment will be collected throughout the development process and presented to the M&S PM and User upon delivery of the accredited simulation. The User should keep this information with other documentation and reports of the simulation's usage. Portions of it should also be included in the simulation's configuration management program. Because there is no assurance that the Developer will remain associated with the simulation after its delivery, this information may be the only way a permanent record of the development process can be maintained. A complete archive of formalized development products should include items such as those shown in the table below.

Development Products Archive
• Application definition
• Simulation objectives and goals
• Requirements, metrics, acceptability criteria
• Development plan, exit criteria
• Validated conceptual model
• Verified designs
• Test data, scenarios, and results from each development phase

Development Products Archive (continued)
• Changes made at each development phase
• Implemented code
• Instance (input) data and hard-wired data
• VV&A plans, V&V reports, Accreditation Assessment report
• Accreditation decision

Other information, such as traceability data, should be archived when available. Additional information about VV&A archive documentation is available at the [VV&A archive](#) link.

Cost Implications and Resourcing

Although V&V resources are normally allocated separately, there can be costs and resources involved in supporting the V&V effort that should be accounted for in the development plan. In particular, the development personnel involved in providing support to V&V activities (e.g., the dedicated point of contact, persons conducting quality assurance assessments, developmental and operational testers) and the time involved in supporting these activities should be budgeted in the development plan to ensure they do not come at the expense of a later phase of development.

Addressing V&V issues and problems promptly as they are discovered can benefit the development process by allowing corrections early, before they become a major scheduling and cost issue. However, the Developer needs to budget the resources, including appropriate personnel and adequate time to work with the V&V Agent and incorporate the necessary corrections.

The intended use of the simulation should be one of the factors considered in determining the amount of development resources to spend supporting the V&V effort.

Example:

A simple simulation used to drive exercises or support development of thought processes may need only a rudimentary V&V effort. If the decision is made to fund a separate V&V budget, the need for development support should be very low; however, if the decision is made to not provide a separate V&V budget, the entire V&V effort will be resourced from the development budget.

Example:

Simulations used to train people to use complex procedures that involve health or safety hazards and those used to provide information for major force structure decisions affecting national security require extremely high credibility and therefore involve extensive V&V efforts. The Developer can expect to provide ample support for individual V&V tasks as well as considerable rework to ensure that the resulting simulation can achieve the high level of credibility required.

Many verification tasks can be conducted in conjunction with regular development activities, and they may involve the use of members of the development team to run tests or collect data. When the development effort is considered small and straightforward, the V&V tasks may be conducted by the Developer as part of the quality assurance program. In this situation, the Developer needs to ensure that adequate resources are available.

In either situation, the Developer needs to consider the nature of the V&V activities required to support the accreditation decision, the amount and types of involvement by the development team, and the development resources needed to accomplish these activities and address them in the development plan. Careful analysis during the planning process should identify the resources required and the costs involved.

Example:

Although there is some flexibility in identifying and providing resources for specific verification and validation tasks, experience in the Joint Warfare System and Joint Simulation and Integrated Modeling System programs indicates that the Developer's support and participation throughout the V&V process and the accreditation assessment are required for the successful development of a new simulation.

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Acronyms

DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
GTE	General Telephone Electronics
IBM	International Business Machines
JADS	Joint Advanced Distributed Simulation
M&S	Modeling and Simulation
MA	Massachusetts
NJ	New Jersey
PM	Program Manager
SME	Subject Matter Expert
T&E	Technical Engineering
V&V	Verification and Validation
VV&A	Verification, Validation, and Accreditation

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