Requirements

RPG Special Topic

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This document corresponds to the web version of the VV&A RPG Special Topic of the same name and date. It has been modified to make it suitable for printing. This document replaces the 11/30/2000 version. It contains updated material and formatting changes.

Introduction

One cannot overstate the criticality of a good set of requirements to system development, in general, and to simulation system development, in particular. The example below, although specifically addressing software requirements, applies to simulations as well.

> Example:
>
> Many software project failures have been attributed to requirements engineering issues. These include poorly documented requirements, requirements that were impossible to satisfy, requirements that failed to meet the needs of users, and requirements creep—the gradual inclusion of unanticipated, undocumented, and poorly considered requirements.
>
> Even when projects do not fail outright, software developers now recognize that errors occurring early in the development life cycle, particularly at the requirements definition stage, turn out to be the most difficult and costly to fix. This is especially true when the errors are not discovered until late in the life cycle—perhaps at implementation. [SEI, 1999]

Few would debate the importance of good requirements to the success of developing or using a simulation for a particular purpose. But, what constitutes a "good" requirement? The following table summarizes many characteristics of good requirements. This document builds upon these aspects to provide insight into the process of developing good requirements for both new and modified simulations as well as for legacy simulations and simulation compositions.

Characteristics of Good Requirements
• Clear and unambiguous, with unique designation for each specific requirement
• Perspicuous, expressed in a way that can be understood by the User, domain subject matter experts (SMEs), and the Developer to mean the same thing
• Even obvious requirements are stated (User and Developer may differ about what is "obvious")
• Consistent with other requirements for the simulation
• Complete so that simulation functionality will satisfy objectives
• Testable (or, at least, satisfaction of a requirement can be demonstrated in some objective and measurable way)
• Organized to facilitate requirements modification during the course of the project: – structured topically – ranked as essential (requirement) or as expected or desirable (characteristic, not a rigid requirement) according to what the simulation needs to be able to do – amenable to elaboration as requirements are translated into high-level and then detailed specifications

Characteristics of Good Requirements
• Viable or achievable (a good requirement is not impossible to satisfy; it can be implemented)
• Can accommodate tracing both forward to simulation design and implementation and backward from simulation implementation to the original objectives (statement of requirements in a formal paradigm may facilitate this)

This document organizes the discussion of simulation requirements, their derivation and use into three broad topics:

- Requirements Characterization – the characteristics of requirements in the context of their discussion in the VV&A RPG [p. 2]
- Requirements Engineering -- how simulation requirements should be generated (their identification and articulation), analyzed and managed [p. 9]
- Requirements Analysis – how requirements should be examined to ensure they are complete, consistent and correct [p. 14]

Requirements Characterization

Usually, one builds, composes, modifies, or applies simulations to satisfy specific requirements, i.e., that collection of functionalities, representations, conditions, constraints, and assumptions that define the needs of a particular simulation use. For new and modified simulations, the simulation conceptual model[1] can supply the transformation from requirements to design specifications that have sufficient detail to ensure that simulation design and implementation will satisfy the User's needs (while not unduly restricting Developer design freedom). Simulation capabilities (developed in response to the set of requirements) enable the simulation to satisfy such needs. The DoD VV&A RPG calls this set of requirements, ***M&S requirements***. M&S requirements specify the set of capabilities that a simulation needs in order to adequately serve all of its intended uses.

The M&S Requirements Flow Diagram [p. 3] depicts a global view of M&S requirement evolution from their inception through the simulation accreditation decision. The activities shown are discussed in the following sections.

Requirement Domains

For simulations, requirements engineering activities begin with information from three domains: ***problem domain***, ***user domain***, and ***simulation domain***. Subject matter experts (SMEs)[2] are often used in as sources of expert knowledge in each.

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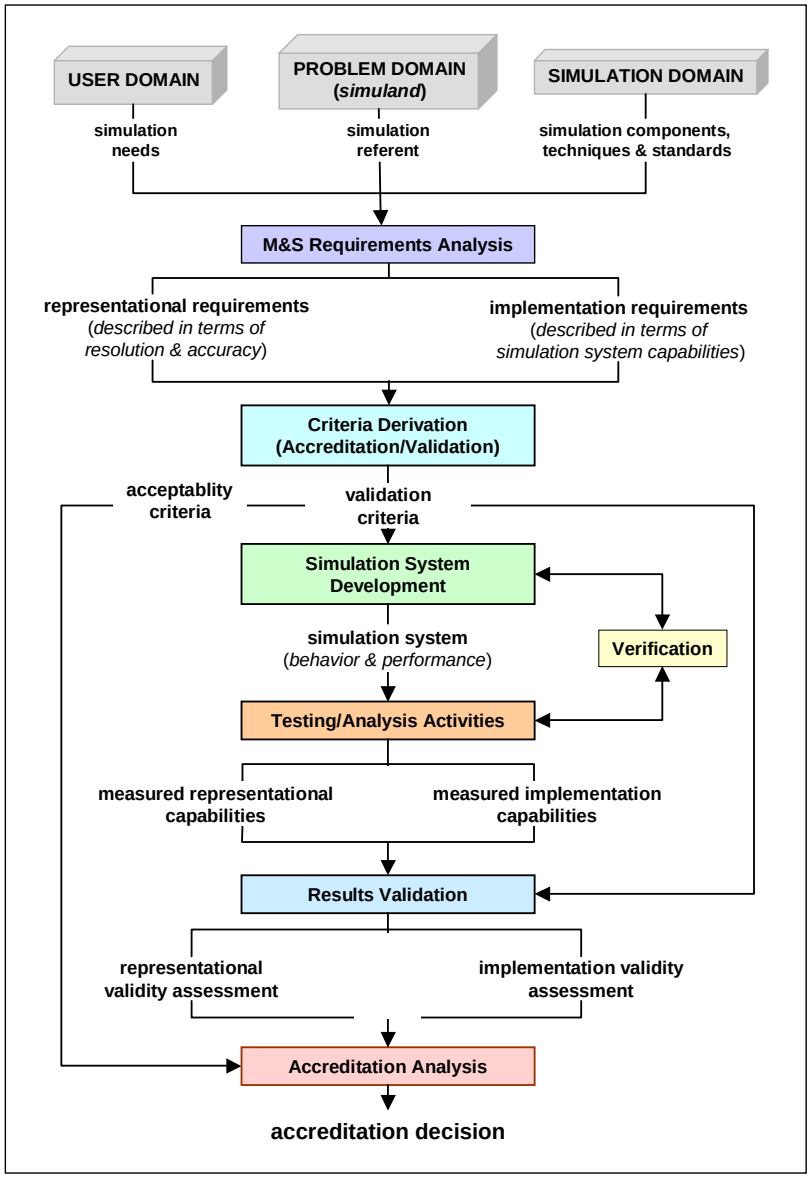
[1] See the special topic on Conceptual Model Development and Validation for additional information.
[2] See the special topic on Subject Matter Experts and VV&A for additional information.



M&S Requirements Flow Diagram

Problem Domain

The ***problem domain*** defines the universe containing the subject or area of interest for the specified problem that the simulation User confronts. Its sphere of interest delimits

the reality that a model, simulation, or federation must represent at a sufficient fidelity[3] to adequately serve a purpose (e.g., command and control, attrition, movement and maneuver). Typically this domain is broad because it includes the entire area from which information can be obtained about the subject of the application (e.g., force structuring analysis; staff level training; analysis of alternatives for a system acquisition decision).

Requirements that depend upon information from the problem domain normally concern the nature of the problem (e.g., functionality (laws of physics); general missions; forces, systems, doctrine) and the overall level of representation needed to produce the desired results. Requirements derived from the problem domain describe the nature of the simuland. In addition, the referent, needed to gauge simulation accuracy, is drawn primarily from the problem and user domains and may be described in the simulation context of the simulation conceptual model. Much of the problem domain will be captured in the *simulation context* of the simulation conceptual model.[4]

User Domain

The ***user domain*** defines the universe describing the specific subject or field of use. Requirements derived from user domain knowledge add the specifics to the M&S requirements that are needed to address real-world or realism issues. Subject matter experts (SMEs) usually supply user domain knowledge. They add detail about exactly how the entities, actions, tasks, and interactions occur within the constraints and assumptions of location, season, weather, and specific force structures. The user domain's sphere of interest delimits the User's particular needs for which the model, simulation, or simulation federation will be applied. It includes the intended methods for applying a model, simulation, or simulation federation to a specific use. Much of the user domain will be represented in the *mission space* of the simulation conceptual model.

Simulation Domain

The ***simulation domain*** describes what the model or simulation needs in order to stand as a practical solution to a problem. Its sphere of interest generates the methods-driven response to providing a solution to problem and user requirements. Requirements associated with the simulation domain define such characteristics of the simulation as the operating hardware and software, algorithms, data and data formats. They also describe the hardware and software environment needed to implement a model or simulation, including simulation architecture, software languages, simulation management capabilities, visualization capabilities, user interfaces, interfaces to other systems, operating requirements, etc. These requirements address the issue of how the simulation implementation accommodates the requirements derived from the user

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

and problem domains. The *simulation space* of the simulation conceptual model will contain much of the simulation domain.

Practical Examples

This table provides a sample list of requirements for several problems a simulation might be asked to address together with the domains from which they come.

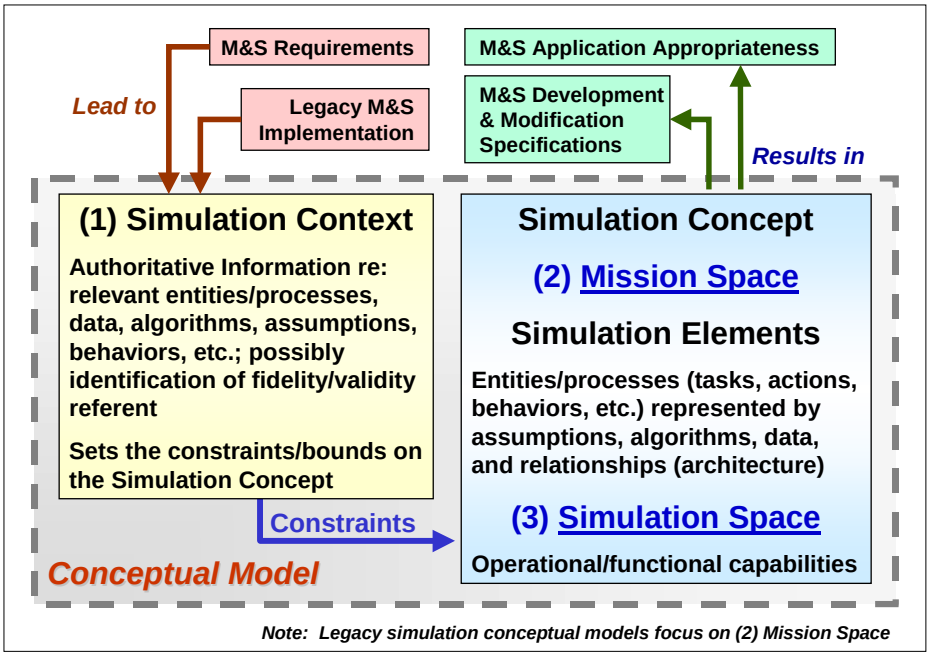
M&S Requirements for Specific Problems		
Derived from the Problem Domain	**Derived from the User Domain**	**Derived from the Simulation Domain**
Problem: Train staff in developing Air Tasking Orders (ATOs)		
• General Theater setting • General Blue/Red OB • Theater C4I • Doctrine	• Specific Blue/Red OB • Specific Command Post • Season, Hour, Weather • C4I Interfaces • Tactics	• Computer Hardware • Software Coding Type • DBMS, Data Formats • Simulation Architecture • Simulation Interfaces
Problem: Determine the best course of action for a Contingency		
• General Theater setting • General Blue/Red OB • Theater C4I • Doctrine	• Specific Blue/Red OB • Specific Command Post • Season, Hour, Weather • C4I Interfaces • Tactics	• Computer Hardware • Software Coding Type • DBMS, Data Formats • Simulation Architecture • Simulation Interfaces
Problem: Train an F-15 aircrew in a simulated flight environment		
• F-15 Flight Characteristics • F-15 Cockpit Layout • Switch Functionality • ROE	• Threat Representations • Season, Hour, Weather • C2 Interfaces • Location, terrain, etc • Tactics	• Computer Hardware • Software Coding Type • DBMS, Data Formats • Simulator Architecture • Simulator Interfaces

M&S Requirements and the Simulation Conceptual Model

It is useful to understand the general relationship between the simulation conceptual model components and the characterization of M&S requirements.[5] A simulation conceptual model has three components: ***simulation context***, ***mission space***, and ***simulation space***, illustrated in the following diagram.

- problem domain requirements relate primarily to the **simulation context**
- user domain requirements relate primarily to the **mission space**
- simulation domain requirements relate primarily to the **simulation space**

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



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Conceptual Model Components

M&S Requirements Development

Users rely on information from the three domains to develop a concise and consistent set of requirements for the simulation at hand. Users use this set of requirements in deciding whether to apply an existing simulation, modify an existing simulation, construct a federation, or build a completely new simulation to serve their purposes. The set of requirements consists of two complementary types of requirements, ***representation*** and ***implementation***.

- **Representation requirements** describe the properties and behaviors of the things that a model or simulation must represent to adequately serve the user's purposes. These include the represented entities, their properties, and the dependencies that, when executed, produce their behavior. Representation requirements define the needed simulation capabilities in the terms of simulation fidelity.[6] These requirements should define the resolution, accuracy, and confidence in that accuracy needed for every object property of importance for directly meeting the user's needs.

[6] See the special topic on Fidelity for additional information.

> Example:
>
> Many simulations use the acceleration of objects falling under the influence of the Earth's gravity (commonly indicated by the symbol "***g***") to characterize vertical motion. Representational requirements would indicate whether the nominal value of 9.80665 m/sec^2 is appropriate for the intended uses of the simulation or if more precise values of ***g*** (dependent upon the exact location on the Earth) are required.

- **Implementation requirements** encompass all of those needs that are not representational in nature, such as the specifics of the interfaces and execution environments (e.g., model execution speed).

Requirements in New Simulation Development

For each new model, simulation, or federation, a set of requirements is developed that governs how it is built (i.e., what the model, simulation, or simulation federation needs to be able to do; its capabilities). These requirements are continuously reexamined and refined as more information is acquired and trade-off analyses are performed during development and the simulation's subsequent reuse. This continual refinement ensures that the M&S requirements are well understood and sufficiently detailed during the development of the simulation conceptual model[7] and, ultimately, the simulation itself. A common simulation development problem is to restrict such requirements refinement to the formal requirements [p. 10] and not to give adequate attention to other requirements, whether explicitly expressed in simulation documentation or not. Such "requirements" also need appropriate approval since simulation capabilities resulting from them consume resources, both to develop and to maintain/use the simulation.

Requirements in Legacy Simulation Reuse

For reuse of a legacy simulation, the User assesses the viability of the simulation through an analysis of the existing capabilities of the simulation and its documentation. Capabilities of the existing simulation are then compared with the requirements needed to address the current problem. The results of this comparison should detail

- which capabilities of the existing simulation will be retained as-is
- which capabilities need to be modified
- what capabilities need to be added to the simulation to make it fit the new intended purpose

All requirements should be reviewed and, when necessary, refined to ensure that they integrate fully into the simulation conceptual model and any subsequent development artifacts.

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

Criteria Derivation

Important to refining requirements is managing “requirements creep” (i.e., expansion of requirements beyond those originally specified to capture the simulation’s intended uses) and to eliminate unrealistic requirements (i.e., requirements that cannot be satisfied by the available technology or resources). Since the derivation of validation or acceptability criteria from requirements statements depends upon the correctness of those requirements, the process of deriving specific criteria usually begins with these steps.

Requirements, although more specific than informally stated User needs, can be quite general in nature and form. Criteria derivation, elaborates from requirements statements the specific and measurable criteria against which a simulation’s behavior will be gauged to determine its success or failure in meeting the gamut of User needs.

- When a simulation is built from scratch or composed from components to satisfy a set of requirements, which enables it to support a variety of purposes (perhaps very similar, and sometimes not so similar), then ***validation criteria*** are derived to represent these requirements. Validation criteria then become the standards against which to demonstrate that the simulation satisfies that full set of requirements representing a range of purposes.
- When the simulation serves a particular purpose, it may need to satisfy only a subset of those broader requirements to perform acceptably for that purpose. One then derives a set of ***acceptability criteria*** to represent the requirements associated with that purpose. In this case, acceptability criteria become the standards against which to demonstrate that the simulation satisfies that subset of the original requirements the accreditation authority deems necessary to judge the simulation suitable for that specific purpose.

Thus, validation criteria represent the full set of requirements to which a simulation is built or composed, and acceptability criteria represent that subset of requirements pertinent to a particular purpose. If one collected all the acceptability criteria for various purposes of a simulation over time, then the collective set of acceptability criteria should equal (or approximate) the set of validation criteria (although it is possible that a simulation might possess some capability that is never exercised for some reason). Additional information on measures and criteria is available in the special topic on Measures.

Simulation System Development

The validation criteria produced by the criteria derivation process, together with their associated requirements, should supply sufficient information from which a new simulation system can be developed. If an existing simulation is being modified to serve a particular purpose, as opposed to a range of purposes, then the acceptability criteria

together with their associated requirements should provide sufficient information to support that modification process.

The simulation development or modification process results in a simulation system to serve the User's intended purposes. The behavior and performance manifested by the simulation enables testing and analysis activities. Testing and analysis activities identify the working simulation's actual representation and implementation capabilities (capabilities that may deviate from those projected from analysis of the simulation conceptual model). Verification processes map the results from these testing and analysis activities back to the development processes.

Results Validation

Results validation assesses whether the simulation's representation and implementation capabilities are complete and correct enough for a particular use. Results validation essentially compares the measurements of simulation capabilities, and their derivations, against the acceptability criteria. Results validation determines if the simulation meets these criteria. It also identifies those criteria that the simulation cannot meet. .

Accreditation Assessment

The information obtained from results validation is used in the accreditation assessment to determine the simulation's fitness for the intended use. In making this assessment, the Accreditation Agent must decide if simulation's capabilities can adequately serve the User's purpose with an acceptable level of risk. This assessment results in a recommendation on accreditation for the intended use. The User, or the designated authority, is then responsible for making the accreditation decision. Because the accreditation is concerned only with the User's intended use, the accreditation assessment relies upon the comparison of the simulation's capabilities against the acceptability criteria for that intended use. In some cases, the acceptability criteria may include all of the validation criteria and in those cases these two criteria sets are equal. This is particularly true when a simulation is being developed specifically to serve a particular purpose.

Requirements Engineering

People have confronted requirements problems since the beginning of large-scale system development. Relatively recently within the systems engineering community, processes addressing requirements issues evolved into a separate discipline, called ***requirements engineering***. This discipline has grown in importance as the complexity of computer-based systems has increased. As a result, requirements engineering envelops a very large literature base in the form of conference and workshop proceedings; journals, journal articles and newsletters; books; and video courses (see the *Requirements Engineering Literature* section in *References*).

Requirements engineering can be broken into three basic functions:

- requirements generation (i.e., how requirements are identified and articulated)
- requirements management
- requirements analysis (including requirements verification and validation)

The following section examines these basic functions in the context of simulation systems. In addition, this section considers the issue of requirements configuration management.

Requirements Identification

M&S requirements can take several forms.

- **Formal requirements** are stated in documents originating from the Users and recognized as defining the capabilities that a simulation should possess to serve a purpose. Normally, a User-designated authority has approved or endorsed formal requirements and they may also be managed in a formal way. Most of the guidance about requirements generation and management in the requirements engineering literature relates to formal requirements.
- **Derived requirements** can be explicitly deduced from the formal requirements and normally are documented in simulation design and development materials. Because they are typically created by simulation development personnel to clarify how the simulation should be developed, derived requirements may not be subjected to review, endorsement, or approval by the User-designated authority [Might and Metz, 2001].
- **Missing requirements** are those needed to fill gaps in the set of formal and derived requirements to ensure the set of M&S requirements for the intended use is complete and consistent. Once they have been acknowledged and approved by the User, they become either formal or derived requirements as appropriate.
- **Undocumented requirements** are hypothetical requirements that may be inferred from existing capabilities of the simulation that may not have arisen in response to formal or derived requirements. (see Appendix A)

Participants in Requirements Identification and Analysis

The primary roles participating in the requirements engineering process include the User, the V&V Agent, the Developer, and the requirements analysis team. They may be supported by others (e.g., Accreditation Agent, M&S Program Manager [PM], M&S Proponent).

Developer

The Developer identifies derived requirements that can be traced back to the User's formal requirements [p. 10]. The Developer may also describe the simulation capabilities corresponding to the M&S requirements relating to both formal and derived requirements and identify those corresponding to undocumented, or inferred requirements [p. 10]. (In legacy simulation reuse, if no Developer is involved, these responsibilities are fulfilled by the person or group responsible for preparing the simulation for use (e.g., M&S PM, User).

The Developer is also responsible for developing the simulation conceptual model. Successful development of an appropriate simulation conceptual model and associated simulation specifications depends on the identification of a complete M&S requirements set. As part of requirements articulation, the Developer should support reorganizing, rephrasing, and recasting User-provided formal requirements to minimize ambiguities and inconsistencies, in accord with ideas in the *Requirements Analysis* section [p. 14]. Derived and inferred requirements should be treated similarly as one prepares a comprehensive M&S requirements baseline. Formal languages and grammars may be helpful as a means of ensuring that requirements are both consistent and logically coherent.

Accreditation Agent

As part of the requirements analysis process described below, the Accreditation Agent can help refine the articulation of M&S requirements by identifying inconsistencies and gaps in them and by describing additional capabilities for legacy simulations (i.e., those capabilities beyond the ones corresponding to formal and derived requirements). Additional "missing" requirements may also be identified during the process of performing other verification and validation tasks (e.g., simulation conceptual model validation; design verification). Missing requirements [p. 10] are those needed to ensure that the simulation will have the capabilities necessary to support its intended uses. Development of the simulation conceptual model and its validation, in particular, are likely to identify both inconsistencies and missing requirements.

As missing requirements are discovered, they should be stated explicitly and proposed to become part of the requirements baseline. Inconsistent requirements should also be made consistent. However, although the Accreditation Agent can assist in this process by making recommendations, it is the responsibility of the User, assisted by the Developer, to resolve requirement consistency problems and to incorporate missing requirements in the set of simulation requirements.

V&V Agent

As part of the requirements analysis process [p. 14], the V&V Agent can help refine the articulation of M&S requirements by identifying inconsistencies and gaps in them. The V&V Agent may also identify missing requirements [p. 10] in the process of performing

other verification and validation tasks (e.g., simulation conceptual model validation; design verification). Missing requirements are those needed to ensure that the simulation will have the capabilities necessary to support its intended uses. Development of the simulation conceptual model and its validation, in particular, are likely to identify both inconsistencies and missing requirements.

As “missing” requirements are discovered, they should be stated explicitly and proposed to become part of the requirements baseline. Inconsistent requirements should also be made consistent. However, although the V&V Agent can assist in this process by making recommendations, it is the responsibility of the User, assisted by the Accreditation Agent, to resolve requirement consistency problems and to incorporate missing requirements into the set of simulation requirements.

The V&V Agent may also discover problems in measuring and testing requirements and criteria and propose changes to better support measurement and testing of simulation capabilities. The V&V Agent and User should discuss issues related to the viability and affordability of demonstrating satisfaction of particular requirements.

The fact that a requirement is not measurable or is inconsistent with other requirements does not diminish the value of that requirement, but these conditions could have significant impact upon how the requirement should be addressed. Requirement inconsistency should be addressed by the User. Specific details of what is inconsistent and recommendations for its resolution should be submitted to the User for a decision.

Unmeasurable requirements may be tested through face validation: One or more SMEs with knowledge about the requirement, aspects of the simuland related to the requirement and aspects of the intended use related to the requirement should evaluate the simulation conceptual model, the simulation results, or both to determine if the simulation possesses the required capabilities. When this occurs, the SME interprets both the requirement and the simulation’s capabilities to assess whether the simulation adequately meets the requirement. This assessment tends to be subjective and potentially introduces unquantifiable error into the validation process.

The inherent subjectivity of face validation also complicates resolving differences in the assessments of different SMEs or the same SME on different occasions. For these reasons among others, requirements that cannot be assessed through an objective measurement process should be avoided whenever practical. However, when face validation is necessary then SMEs should be chosen who the User sees as credible.

There is little difference between a situation in which validation cannot be performed and one in which the validation investigation shows the representational capability of the simulation falls short of the simulation requirement. In both cases, failure to demonstrate that a requirement is satisfied increases the risk in using the simulation for its intended purpose. Whether that increased risk is acceptable is for the User to decide.

User

The User is the original source for the requirements of the intended use and the final authority in setting all M&S requirements by endorsing or approving them for the intended use. The User should assist the Accreditation Agent, Developer and V&V Agent as needed to clarify, understand, and revise the M&S requirements until they result in a sufficient, correct and consistent set. The User should endorse this set so that a comprehensive, authoritative set of M&S requirements exists that can serve as the baseline for simulation development and future simulation usage.

Requirements Analysis Team

Requirements analysis (i.e., requirements verification) [p. 14] is normally done by a group of people that includes, as a minimum, the User or their designated authority, the M&S PM, the Developer, SMEs, the Accreditation Agent, the V&V Agent, and, in legacy simulation reuse, the M&S Proponent. This team has only an advisory role. The User, as the one who has the authority to determine requirements, may or may not heed recommendations and suggestions resulting from the analysis effort.

Requirements Articulation

For both new and legacy simulations, the User maintains the responsibility for articulating a set of M&S requirements that addresses the intended purpose. The User may enlist the aid of the Accreditation Agent, the V&V Agent, the M&S PM or M&S Proponent, SMEs from various applicable disciplines, other past and prospective users, and even the Developer to produce a comprehensive, correct and consistent set of M&S requirements; but, in the end, it is the User who must be satisfied that the set is accurate and complete enough to specify the simulation capabilities needed for the intended use.

When working with legacy simulations, the User may build the M&S requirements for the intended use from the requirements of previous uses. This strategy may reduce the burden of producing comprehensive M&S requirements; however, the User should always carefully review these “adopted” requirements to ensure their applicability to the intended purpose.

> Example:
>
> Software engineers initially focused on programming methods, then on design methods, and are now focusing on requirements methods, in an attempt to introduce more discipline in the software engineering process. In the early days, requirements were developed in English text, but over time have evolved into structured and in some cases formal specifications. More recently there has been interest in requirements elicitation, because working with non-technical people can be among the most challenging areas of software development. [SEI, 1999].

After requirements have been identified and collected so that a comprehensive requirements baseline exists (with appropriate endorsement and approval by the User), the requirements should be reviewed and analyzed (as discussed in the Requirements Analysis section [p. 14]) so that one can derive meaningful validation or acceptability criteria from them. The figure below illustrates this process.

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The User establishes the requirements. The User determines what the simulation should be capable of doing. However, the User may need to consult SMEs[8] with requirements engineering experience in order to articulate the M&S requirements so that the requirements will have the attributes listed in the Characteristics of Good Requirements table [p. 1].

Requirements Analysis

Frequently the initial set of requirements is incomplete, inconsistent, and incorrect in places and analysis is performed to identify and correct these problems. Requirements analysis is the process of reviewing and evaluating requirements to ensure they are complete, consistent, and correct. This activity may also be called requirements verification or validation in some communities. This collection of terms (requirements analysis, requirements review, requirements verification, requirements validation) basically describes any endeavor designed to ensure that M&S requirements have the characteristics of good requirements [p. 1].

In order to improve clarity, this document will refer to the general process of analyzing a requirements set for completeness, correctness, and consistency as ***requirements analysis***. It will specifically use the term ***requirements verification*** to denote the process of confirming requirements completeness, consistency, and correctness with the User or their designated authority. Early requirements verification helps the User gain confidence that the requirements will lead to a simulation that can address their needs efficiently and effectively. Early requirements verification can also identify and thus prevent potentially inappropriate commitments (such as ill-advised specifications or problematic development contracts).

Requirements analysis supports three major purposes:

- ensuring that the requirements are logically consistent, clear and unambiguous, and comprehensive
- supporting the tracing of requirements to (and from) the simulation conceptual model, simulation specifications, simulation design, and simulation implementation

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

- ensuring that the requirements correctly reflect the User's intent

Specific V&V tasks associated with requirements verification are discussed in the function sections of the V&V Agent core documents.[9]

If the requirements contain extraneous elements (i.e., elements that do not contribute to satisfying the User's intent) or if the demands for fidelity[10] are beyond those necessary to achieve the intended purpose, then they can have an impact on resources that may, in some cases, be significant. If the requirements are not stringent enough to ensure that simulation capabilities will adequately serve a purpose, the simulation may produce results unsatisfactory to its users.

Requirements Analysis Techniques

Two of the standard techniques employed in requirements analysis are requirements review and requirements tracing.

- **Requirements Review.** In requirements review, a group of experts carefully examines the M&S requirements set for correctness, completeness, and consistency. Requirements review is usually more effective when the requirements are grouped into different classes (e.g., representation, implementation) are treated by separate groups of experts with specialties in appropriate areas.
- **Requirements Tracing.** In requirements tracing, the products of those activities downstream of the initial user needs articulation are linked by their derivation from or contributions to specific user needs. Several database tools have been developed, and have matured over the past several years, to support requirements tracing [Systems Guild, 2003]. Requirements tracing is a straightforward, albeit somewhat tedious for large systems, task of incalculable value.

To support V&V activities, requirements should be traced through all simulation development phases. A requirements database could also reference the V&V tools[11] and techniques that are used relative to the requirements, to any test cases and test scripts applied, and to the results of V&V efforts. It is important to be able to relate simulation system components to requirements so that items that are not driven explicitly by specific requirements can be identified. Likewise, tracing from validation results back to requirements is essential to support risk management for effective accreditation decisions. Additional information about these and other techniques is available in the reference document on V&V techniques.

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[9]See the core documents on the V&V Agent Role in the VV&A of New Simulations and the V&V Agent Role in the VV&A of Legacy Simulations for additional information.
[10]See the special topic on Fidelity for additional information.
[11]See the reference document on V&V Tools for additional information.

Administrative Structure

A common problem with simulation development is the lack of an administrative structure that supports early requirements verification, with the consequence that a formal requirements verification effort often begins after inappropriate development decisions and resource commitments have been made. Mechanisms to enable early analysis are important, but it is better to do requirements verification late than not at all.

Requirements Management

The following table presents some good practices for managing requirements, an assessment of the costs to introduce and apply each practice, and the key benefits resulting from those practices [Sawyer, et al, 1999].

Requirements Management Good Practices			
Task	**Cost to Introduce**	**Cost to Apply**	**Key Benefit**
Uniquely identify each requirement	Very low	Very low	• Provides unambiguous references to specific requirements
Define policies for requirements management	Moderate	Low	• Provides guidance for all involved in requirements management
Define traceability policies	Moderate	Moderate to high	• Maintains consistent, traceability information
Maintain a traceability manual	Low	Moderate to high	• Records all project-specific traceability information
Use a database to manage requirements	Moderate to high	Moderate	• Makes it easier to manage large numbers of requirements • for small endeavors, use of a database approach is no more costly than manual methods
Define change management policies	Moderate to high	Low to moderate	• Provides a framework for systematically assessing change
Identify overall system requirements	Low	Low	• Finds requirements likely to be most expensive to change
Identify volatile requirements	Low	Low	• Simplifies requirements change management
Record rejected requirements	Low	Low	• Saves repeating analysis when rejected requirements are proposed again (should include rationale for rejection)

Requirements Configuration Management

Configuration management is an important aspect of requirements management. Additions, refinements, and other changes to the set of M&S requirements are inevitable during the development and life cycle of a simulation. The original

requirements set provided by the initial User often grows during the project as the participants refine requirements, derive requirements, make inferred requirements explicit, and identify missing requirements. The configuration management process should support efficient but controlled changes to the requirements set. The requirements database should track when and by what authority changes and additions are made. The individual or group authorized to change or add requirements must balance responsiveness to genuine project needs with the importance of achieving requirements stability during the development and the problems of "requirements creep."

Change authorization should be a formal process, preferably aided by automation, to keep the process responsive (e.g., a configuration control board (CCB) or review panel whose members are able to assess the programmatic and technical impacts on development and V&V). All change requests should be documented and provided to the V&V Agent. The V&V Agent should then assess the impact of each change on simulation validity as well as on the total set of requirements. Regression testing can be used to ensure that the original capabilities remain intact. The V&V Agent should inform those authorized to approve requirements changes of such impacts.

The configuration management process established for a simulation can be useful in the V&V process. Characteristics of a good configuration management system from the V&V perspective include

- strict control of requirements (establishing a comprehensive requirements baseline is a fundamental element of requirements control)
- stability of requirements (considered, deliberate changes)
- effective version identification
- a solid trace of requirements (down to each supported version and to the simulation system components associated with each requirement, and which allows clear identification of simulation system components which are not specifically related to approved requirements).

However, if a distributed simulation application involves several simulations, several different configuration management programs may be involved. Developing an overall configuration management process to address the needs of the overall federation, which also embraces the configuration management processes of the individual federates can be extremely challenging.

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Requirements Engineering Literature

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

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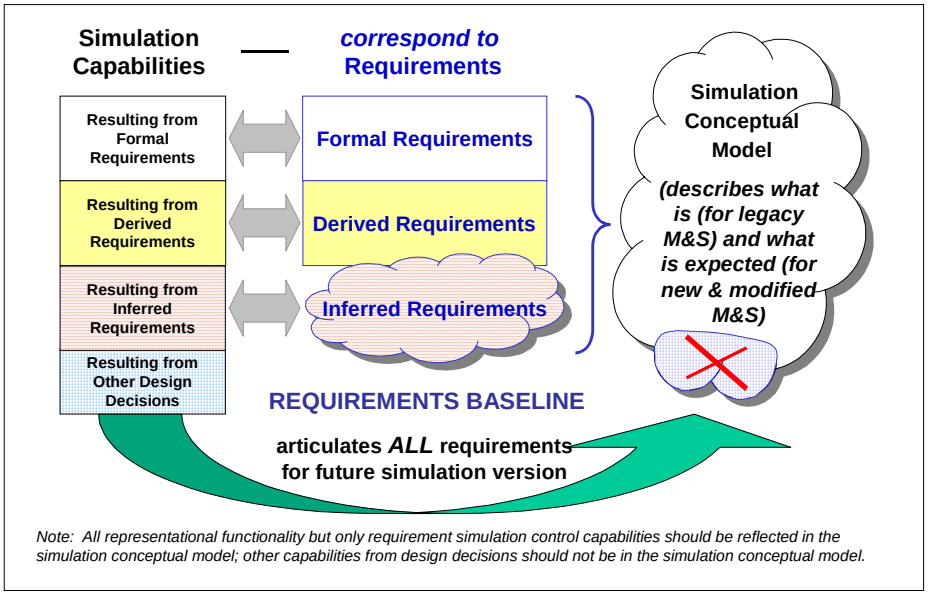
In the web-based version of this document, the appendix below appears as a hot link in the *Requirements Engineering* (*Participants in Requirements Identification and Analysis*) section.

Appendix A: Inferred Requirements

For legacy simulations, there are also **undocumented requirements** that might be inferred from existing capabilities of the simulation. These capabilities in an as-is simulation may not have arisen in response to formal or derived requirements. Many legacy simulations have capabilities that lie beyond any documented requirements (formal or derived) that exist for the simulation. It is helpful to relate those capabilities to requirements so that a complete baseline of requirements for the simulation can be articulated that can be reviewed, approved, or modified if the simulation is to be modified for future use (as illustrated by the relationships of simulation capabilities, requirements, and the simulation conceptual model in the following figure).



Simulation Conceptual Model Relation to Requirements and Capabilities

The term "**inferred requirements"** describes this situation. It should be noted that inferred requirements are not necessarily unique in that more than one requirement (or set of requirements) could lead to the same capabilities. It should also be noted that some capabilities of a legacy simulation are simply the result of design decisions (the choice of software operating environment is often such a decision), not necessarily a response to requirements. As legacy simulation capabilities are analyzed, it is

important to separate such design decisions from inferred requirements as a requirements baseline is developed.

The primary reason for discussing simulation capabilities in terms of requirements is because capabilities consume resources, both in simulation development and in simulation maintenance and use. Resource consumption for additional capabilities in simulation development is obvious. Since the authority establishing simulation requirements also often has responsibility for simulation funding, they should decide whether to pay for any capabilities beyond those required to serve the User's purpose.

However, for legacy simulations, the issue is not the cost of developing the excess capabilities (i.e., those beyond stated requirements), the issue is the cost of using and maintaining the simulation with such excess capabilities. Resources may have to be spent in additional training for personnel relative to those capabilities, in additional effort collecting and organizing simulation inputs related to those excess capabilities, and in additional effort analyzing simulation results to ensure that no untoward behavior was caused by interaction with the excess capabilities (every additional capability in the simulation is another source of potential problem as well as capability).

Sometimes simulation capabilities beyond those required by documented requirements for the simulation are the result of a response by the simulation developer to perceived (or expressed) interested by a User (or potential User) of the simulation (i.e., a "customer" from the developer perspective), or an unanticipated consequence of how the simulation was developed.

The wisdom and importance of developing a comprehensive set of requirements (i.e., the requirements baseline) for a new or modified simulation is obvious; otherwise, it will not be possible to determine if the simulation design and implementation fully satisfy the requirements. Some may question the need for developing such a requirements baseline for a legacy simulation. Questions of simulation appropriateness for potential applications can be answered from descriptions of simulation capabilities (and, in some cases, could be answered from even a partial description of simulation capabilities). Description of capabilities is the primary content for the simulation conceptual model of a legacy simulation. It is suggested that when a simulation conceptual model is developed for a legacy simulation, a requirements baseline related to its capabilities should also be developed to facilitate future evolution of the simulation since most significant simulations continue to be used for a long time.

For some legacy simulations that have limited documentation of formal and derived requirements, most of the requirements for the simulation may be inferred from simulation capabilities.

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