Foundations for Verification and Validation of the Natural Environment in a Simulation

RPG Special Topic

4 August 2004

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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.

Introduction

This document discusses the benefits and challenges associated with implementing an appropriate environmental representation in a simulation and presents ways of developing foundations for its verification and validation. Throughout the document, the phrase ***simulation development*** is used to describe the process involved in preparing any simulation for use.

- When a new simulation is involved, this phrase refers to the process of creating the simulation beginning with the identification of requirements and ending with the accreditation of the simulation for the intended use.
- When a legacy simulation is involved, this phrase refers to the process of evaluating the simulation to determine if it can be used ***as-is*** or if it needs modification, extending through any necessary modifications, and culminating in its accreditation for the intended use.
- When a simulation federation or suite or models is involved, this phrase refers to the process of building the federation or suite, beginning with the identification of the requirements and objectives and ending with its accreditation for the intended use.

In this document, the assumption is made that simulations are *mission space-oriented*. The term ***object*** is used to refer to *things* represented in a simulation, rather than ***objects*** in the sense of *object-oriented,* and ***entity*** is used to refer to the real-world *things* being represented.

> Example:
>
> The term ***mission-space object*** is used to describe the simulated representation of a real world object and the term ***mission space entity*** is used to describe the real world "thing" that is being represented by a simulation battlefield object.

Simulation ***objects*** have characteristics and may also have behaviors, but their interactions with other simulation ***objects*** are frequently not known and not assumed.

Early simulations included mission space objects and their characteristics and performance data without respect to external influences (environmental effects and impacts, human and organizational behaviors). A demand for greater realism led first in the addition of one-way object behaviors, which were modeled with and without external influences, and later to the addition of two-way object interactions. Although these two-way interactions usually incorporated some representation of external influences on each interaction, the representation was not necessarily consistent.

> Example:
>
> A military tracked vehicle rolling through a minefield might set off a mine, resulting in damage to the vehicle. However, no crater is formed in the terrain surface such that subsequent movement along the same route through the minefield is impeded.

In addition, the interoperability requirements of simulations participating in federations and joint exercises today often specifically include environmental influences on objects, their behaviors, and their interactions within and across simulation boundaries.

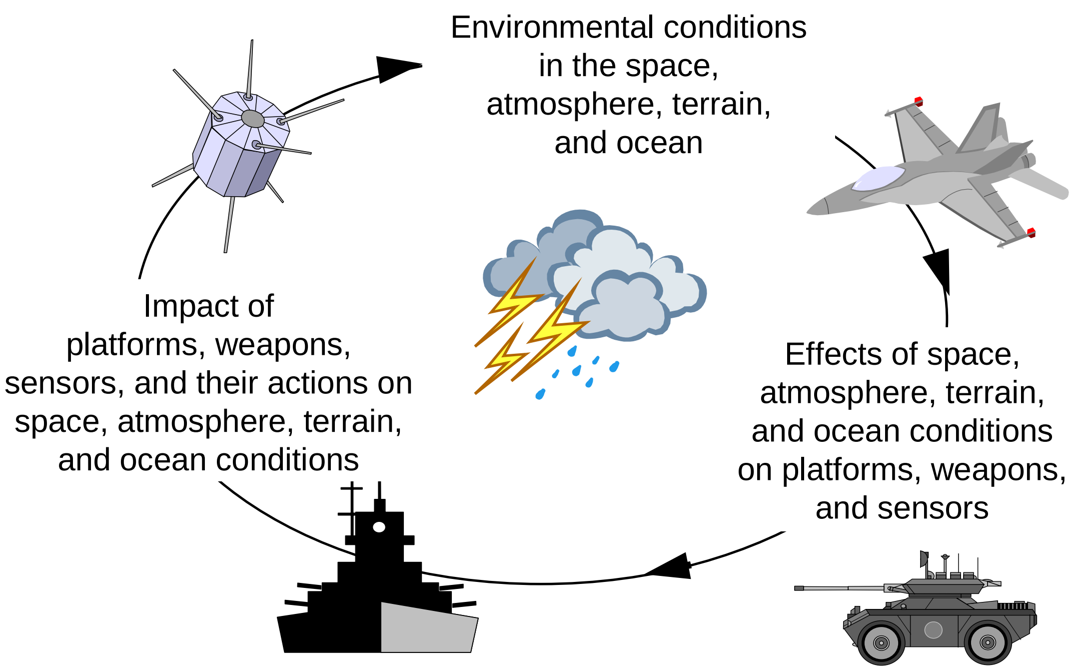
In early simulations, the environmental representation was depicted as a uniform background region within which the simulation was run. Sunshine, clouds, precipitation, and heat may have been identifiable simulation elements, but they had limited, if any, effect on the behaviors of the mission space objects or incorporation into algorithms (e.g., line-of-sight determination, cross-county movement calculations).

> Example:
>
> In the original Simulation Networking (SIMNET) system, it was always "noon, on a clear day."

As the art and science of simulation development began to evolve and related requirements emerged, characteristics of the physical environment were incorporated into object behaviors. Because these behaviors were primarily developed as pre-set changes in object performance, it was difficult for the User to know whether the environmental representation was consistently affecting different mission space objects in the same scenario. As state-of-the-art simulations begin to leverage major improvements in simulation technology, there is an increased need to better depict the physical environment and its interactions with mission space objects within a simulation and across a federation of simulations.

Representing the Real World: Environment/Entity Interactions

The goal of any simulation is to provide a representation of real world entities and their environment from the perspective of the intended application. This goal can best be achieved by properly depicting the physical environment within the simulation so the scenario and its mission space objects and behaviors, given the same context, can be represented as closely as possible to the way they would be in the real world. This relationship is depicted below.



Environmental Interactions

> Example:
>
> This circular chain of interactions is illustrated using terrain soil conditions, a military vehicle, and the battlefield. Trafficability of military vehicles is determined by the actual terrain soil conditions—moist soil has a clogging effect on vehicle traction, and very soggy soil has a significant impeding effect on tank movement. As the vehicle moves across the terrain, it can impact the terrain skin enough to change trafficability conditions for other equipment and personnel traversing the same path. In assessing terrain conditions for subsequent simulation activities, these changes should be incorporated properly to maintain a high degree of environmental realism in the simulation.

Thus, the earlier concept of the environmental representation as a set of unchanging *environmental conditions* needs to be expanded to include the two-way interactions of the environment with *mission space entities*.[1] The first half of these interactions is termed *environmental effects*, and the second half is termed *environmental impacts*.

A realistic simulation environment, therefore, would include these interactions according to the following three levels of environment/entity interactions:

[1] Throughout this document, the term mission space entity is used to describe the real world "thing" that is being represented by a simulation "mission space object."

- **environmental conditions**: the characteristics of the physical environment, in one or more of four environmental domains (i.e., space, atmosphere, terrain, ocean), commensurate with, but independent of, any mission space entity with which it may come in contact
- **environmental effects**: changes in a mission space entity's state or performance caused by the interaction of one or more environmental conditions with its characteristics and performance
- **environmental impacts**: changes in one or more environmental conditions caused by one or more system performance characteristics or activities of a mission space entity

These interactions can occur within a single environmental domain, or can span the boundaries of two or more of the four environmental domains.

Categories of Environment/Entity Interaction

The identification of specific environmental effects and impacts to include in a simulation can be challenging. One ordered approach to use is to first establish a set of functional categories[2] into which the spectrum of operations required by the scenario (e.g., military operations) can be divided. Using these, the set of environment/mission space entity interactions can be progressively identified, considered, and developed.

This approach was used in the Joint Simulation System (JSIMS) Terrain Common Data Model [Lockheed Martin et al, 1999], which identified five basic functional categories of mission space entity interactions with the environment:

- Trafficability [p. 4]
- Sensors [p. 5]
- Intervisibility [p. 6]
- Weapons [p. 6]
- Infrastructure [p. 6]

Regardless of whether the representations of the interactions in these categories are explicitly depicted or are implicitly captured in assumptions or calculations of object performance within the simulation, the environmental data needed to simulate them should be captured in the simulation's conceptual model.[3]

Trafficability

[2] The set established should reflect the needs of the intended application.
[3] See the special topic on Conceptual Model Development and Validation for additional information.

Environmental effects on the movement of military forces and equipment involve the interactions of the mission space entities with their environmental domain(s) of transport (space, air, land, or water) and with the atmospheric environment at the interface of the atmosphere with the space, land, or ocean domain(s) of transport.

> Example:
>
> Aircraft flight parameters and ship/submarine, surface and subsurface movement characteristics are specific examples of trafficability in the atmosphere and ocean domains, respectively.

Environmental impacts involve changes to the domain of transport caused by the interaction of the mission space entity with that domain. These impacts should include the set of changes to the atmospheric environment at the interface between the atmosphere and the domain of transport.

> Example:
>
> The mud or dust clouds created by tank movement not only change the terrain elevation but can also change the thermal character of the lowest layers of the atmosphere.

Sensors

Environmental effects on mission space entity sensor components involve interaction between the mission space entity and sensor emissions for active sensors and interaction between the mission space entity emissions and the medium[4] through which the emitted energy propagation occurs for passive sensors. Additional factors that determine the environmental effects on sensors include

- type of energy emitted (electromagnetic or acoustic)
- frequency at which the energy is emitted
- manner in which the emitted energy is reflected off the target and receiving mission space entity (for active sensors) or the receiving mission space entity (for passive sensors)

Environmental impacts caused by mission space entity-emitted energy and entity sensor-emitted energy interactions may result in changed characteristics of the environmental conditions. As the propagated energy passes through the environmental medium, these changing environmental characteristics may alter the density structure of the environment enough to result in a significant alteration of the energy propagation path.

[4] Types of media that can occur in the mission space are categorized as ***solids*** (e.g., ice or terrain), ***liquids*** (e.g., the ocean), and ***gases*** (e.g., the atmosphere).

Intervisibility

Intervisibility is a special instance of the sensor category. It involves two-way energy propagation of sensors located on two different mission space entities, the interaction of the transmitted energy with the environment along the entire propagation path of both sensors, and the ability to spatially track (in two, three, or four dimensions, as desired) the propagated energy of both sensors to identify points in common. Intervisibility is not limited to visual wavelengths, but encompasses the ability of two sensors to detect each other's existence by sharing common points of coverage in emitted energy.

Intervisibility interactions can span the range from very simple to very complex, depending upon the rigor required by the representation. The environmental impacts involved are similar to those for sensors, but with some changes.

- ***Simple interactions*** include the ability of one observer to (visually) see another
- ***Moderately-complex interactions*** include the ability of a platform to receive communications transmissions at various frequencies from a variety of transmitters or to transmit so that the emissions are received by the appropriate transmitters
- ***Complex interactions*** include the ability of a ship to evade the passive detection and active targeting sensors of mines in a minefield, and the ability of a radar to detect and identify a distant surface or airborne target

Weapons

Environmental interactions with mission space entity weapons must be recognized both in the case in which a weapon is considered an integral part of the mission space entity and in the case in which a weapon is a separate, but related, part of the mission space entity. While the effects of the environment on targeting sensors should be considered as a sensor interaction, this category addresses interactions of the environment with a specific warhead (e.g., missile, bomb, mine explosive) as well as with the weapon case and any applicable equipment used to project the warhead (e.g., altered offset aim points, changed missile flight paths).

Environmental impacts of mission space entity weapons focus on interactions of all four environmental domains with a detonated or undetonated warhead.

Examples:

- the crater and related cloud of dust and heavier ejected material caused by the explosion of a bomb when it hits the terrain
- the changed performance of sensors when subjected to an electromagnetic pulse
- the changed terrain or bathymetry caused by the laying of a minefield

Infrastructure

Environmental interactions with military infrastructure elements (e.g., combat obstacles and military engineering, logistics) and civilian infrastructure elements (e.g., existing facilities, structures, networks, features not related to military operations) involve fusion of multiple types of environmental and mission space information, such as the geospatial positioning of terrain, cultural features, and targets of interest to the mission space entities. This set of interactions also includes the interaction of environmental phenomena (including hurricanes, tornadoes, and other severe storms) in all four environmental domains on infrastructure features such as buildings, bridges, and harbors. The effects include

- correct placement of battle damage on simulation displays
- correct placement of battle damage in the stored mission space representation
- ability to place or update the effects of military engineering projects on displays and in the stored mission space representation

Environmental impacts of infrastructure elements may result in changed features on simulation displays and in the simulation mission space representation database caused by battle damage or initiated engineering projects, whether civilian or military.

Challenges of Representing Environment/Entity Interaction

Moving a simulation and its objects toward an increasingly accurate representation of the real world presents definite challenges in the development or modification of a simulation. By category, the challenges of representing environment/entity interactions are summarized in the table below.

Challenges of Environmental Effects and Impacts by Environment/Mission Space Entity Interaction Category				
Trafficability Interactions				
Environmental Domains:	• space	• atmosphere	• terrain	• ocean
Environmental Effects:	• Interaction of environment with mission space entity (changed entity movement performance; changed entity characteristics)			
Environmental Impacts:	• Changes to environmental conditions caused by mission space entity			
Environmental Challenges::	• proper correlation of mission space entity with surrounding environment • consistency of effects and impacts across environmental domains			
Sensor Interactions				
Environmental Domains:	Domains through which sensor energy propagates: • space	• atmosphere	• terrain	• ocean

Challenges of Environmental Effects and Impacts by Environment/Mission Space Entity Interaction Category	
Environmental Effects:	• Interaction of the medium (air as gas and vapors; ocean and inland waters as liquid; rock, soil, land cover, and ice as solids) through which the sensor energy is propagated with the sensor transmitted energy
Environmental Impacts:	• Changes to the sensor's background medium caused by propagated energy all along the propagation path
Environmental Challenges:	• proper correlation of mission space entity with surrounding environment • proper correlation of energy propagation path with related environment
Intervisibility Interactions	
Environmental Domains:	Domains where mission space entities are located and domains through which two-way sensor energy propagates: • space • atmosphere • terrain • ocean
Environmental Effects:	• Interaction of the medium(s) through which both sensors' energy is propagated with the sensors' transmitted energy
Environmental Impacts:	• Changes to the sensors' background medium(s) caused by propagated energy all along the propagation path
Environmental Challenges:	• fusion of multiple types of environ-mental and mission space information • precise positioning of mission space entities and features of the complete environment between them
Weapon Interactions	
Environmental Domains:	Domains through which the warhead passes: • space • atmosphere • terrain • ocean
Environmental Effects:	• Effects of the environment on warhead movement, detonation, and damage pattern
Environmental Impacts:	• Changes to the environment caused by weapon detonation and resulting damage
Environmental Challenges:	• fusion of multiple types of environmental and feature data • precise positioning of targets, detonation, and damage pattern
Infrastructure Interactions	
Environmental Domains:	• space • atmosphere • terrain • ocean
Environmental Effects:	• Effects of environmental phenomena on infrastructure features
Environmental Impacts:	• Changed features on simulation displays and in the simulation mission space caused by battle damage or engineering projects
Environmental Challenges:	• fusion of multiple types of environmental and cultural feature data • precise positioning of environmental phenomena and infrastructure features

Some challenges can occur regardless of the category of interaction. These challenges include:

- the need to ensure the physical consistency of the included environmental representation, both within each domain and across each domain boundary
- the potential need to ensure a consistent application of the environment, with its effects and impacts, to ensure fair play within and across simulations
- the need to identify, verify, and validate embedded environmental effects models in mission space object models
- the need to properly characterize the lag time in the environment's response to an environmental event, ensuring the appropriate spin-up or spin-down period for these responses (e.g., a higher sea state due to increased swell for a period of days after passage of a storm system)
- the need to properly compress or eliminate the natural transition time in moving from one environmental state (e.g., calm winds, rain squall, clear and sunny) to another (e.g., calm winds→strong, gusty winds, rain squall→calm winds and no ceiling, clear and sunny→full-force hurricane)

Incorporating an Environmental Representation in a Simulation

The key to incorporating an environmental representation in a simulation is to determine what environmental aspects are needed to address the M&S requirements of the intended application. The mission space entities to be represented in the simulation have multiple dimensions, some that will need to be incorporated in the simulation and some that will not. In the real world these entities exist in an environment and their status and behaviors are defined to some extent by that environment.

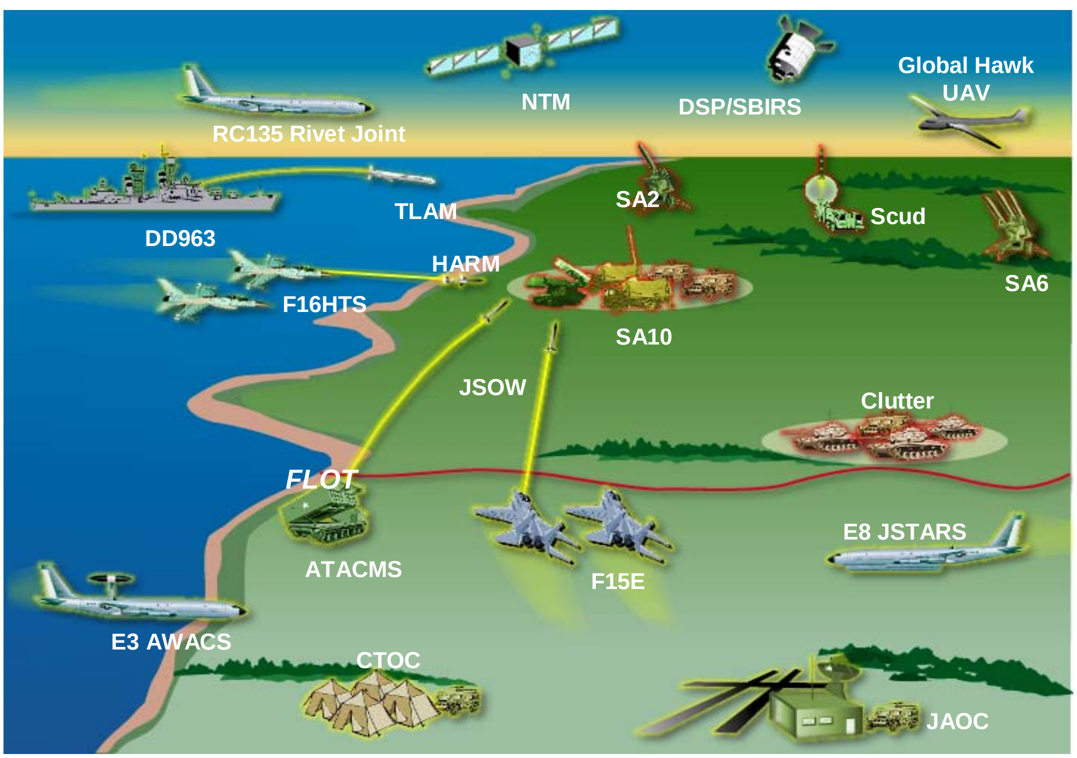
If a mission space object is to represent its real-world counterpart appropriately, the object behaviors should include the following statements about the mission space entity [Youngblood, 2001]:

- how the mission space entity is positioned in the real world
- how it communicates with other mission space entities
- how it receives sensor information about other mission space entities, both friend and foe
- how it makes decisions (or how decisions are made for it)
- how it reacts in time and space
- how it operates in response to the real world environment around it

Proper depiction of these real-world behaviors makes it possible to address the simulation-level requirements. If a simulation is to be completely stand-alone (i.e., no need to interoperate with other components), then simulation requirements are limited to the software and hardware needs of the current application. However, if the simulation is to be used with other simulations (e.g., as a component in an exercise or suite; as a federate in a federation), then the simulation and its objects also need to support

- ***technical interoperability***, which is the capability of simulations to physically connect and exchange data (without respect to the simulation or federation mission)
- ***substantive interoperability***, which is the capability of simulations, when joined together, to provide adequate, accurate, and consistent simulated representations which adhere to the principles of “fair fight” and address the mission objectives

Building a representation of the real-world environment to support the requirements of the intended use into a simulation involves incorporating environmental conditions, effects, and impacts to more realistically depict how the mission space entity behaves within and with respect to its environment, and ensuring that such depictions are consistent with depictions of the same (or similar) entities in other simulations. The result of designing such realism and consistency into mission space objects is the substantive interoperability depicted in the following figure [Youngblood, 2001].



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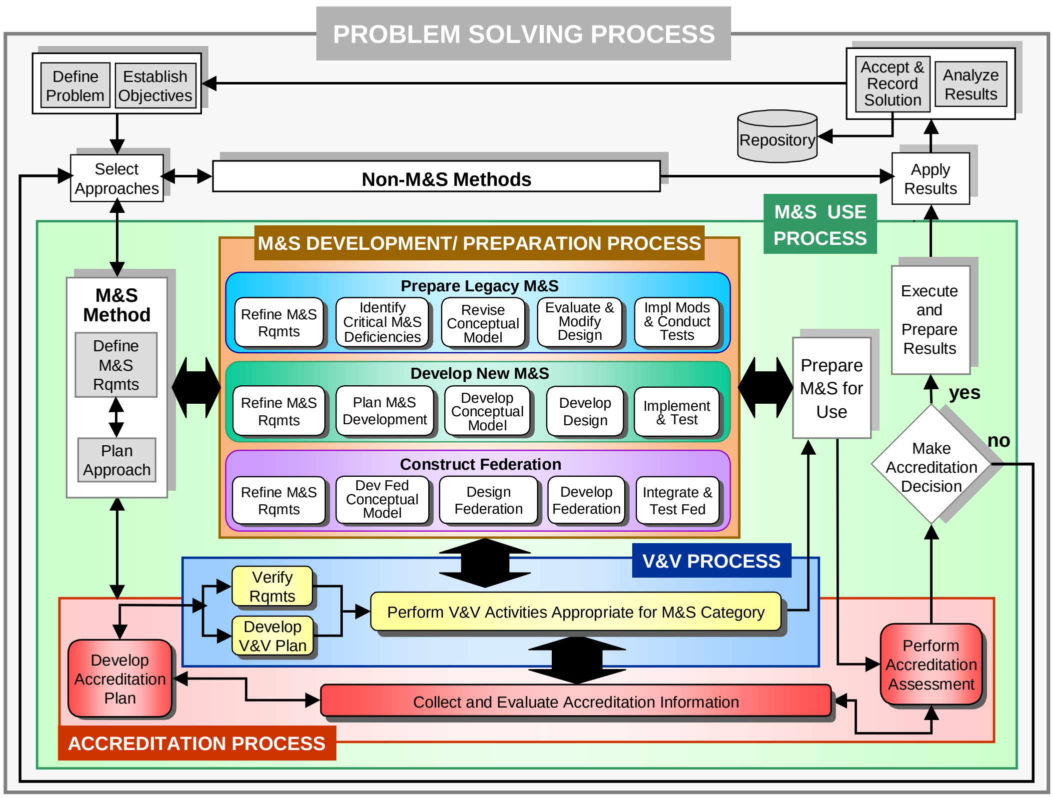
Substantive Interoperability

Environmental Representation and the Overall Problem Solving Process

The need for representing the physical environment is tied to the M&S requirements of the intended use.[5] Incorporating it in the simulation should be an integral part of the Overall Problem Solving Process [p. 11] illustrated in the following diagram. As the M&S requirements are defined and refined, the aspects of the environmental representation (e.g., the physical representation of the environment, environmental conditions, environmental effects on the entities and behaviors being represented, the effects of entities and behaviors on the environment) needed to ensure adequate representation of the requirements should be identified and they, in turn, become requirements for the simulation. Once the type of simulation (i.e., new, legacy simulation, federation) is chosen, these environmental representation requirements are incorporated into the simulation via the M&S development and preparation process.



The Overall Problem Solving Process

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Establishing Requirements for the Environmental Representation

The environmental representation needed in a simulation depends on the requirements of the intended application.[6] In some cases, total environmental support to the M&S Developer or User involves providing a complete four-dimensional, multi-domain dataset, a representation that portrays the environment representation in a physically consistent manner, within and among the relevant space, atmosphere, ocean, and

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

terrain domains, with content and resolution appropriate for the simulation and its intended use. While there is no standard process for determining what the environmental representation should be, there are some questions that can help identify what environmental effects and impacts are needed based on the requirements of the intended application. These questions, listed in the following table, can be used as a checklist for identifying the desired object behaviors that should result from interactions of objects with the environment as well as the environmental data needed to support them. The table is divided into two parts: the first part [p. 12] applies to all simulations, whether stand-alone or part of a federation; the second part [p. 13] applies only to federations (which require as input a set of models or simulations that have each been examined in accordance with the first part of the checklist).

Required Environment/Object Interactions Checklist	
Does the model or simulation require a physical environment?	√
• Does the model or simulation require a physical environment in the space domain?	
• Does the model or simulation require a physical environment in the atmospheric domain?	
• Does the model or simulation require a physical environment in the terrain domain?	
• Does the model or simulation require a physical environment in the ocean domain?	
What is the spatial scale of the model or simulation? *	√
• Is the model or simulation at a strategic scale?	
• What global-scale physical parameters are required by the model or simulation?	
• Is the model or simulation at a theater tactical scale?	
• What synoptic-scale physical parameters are required by the model or simulation?	
• Is the model or simulation at a battlefield scale?	
• What mesoscale physical parameters are required by the model or simulation?	
• Is the model or simulation at the scale of an individual mission space entity?	
• What microscale physical parameters are required by the model or simulation?	
• Is the model or simulation at an engineering-level scale?	
• What molecular-level physical parameters are required by the model or simulation?	
Does the model or simulation require differentiation between day and night?	√
• Is this diurnal differentiation sufficient to meet the M&S requirement?	
• What other details (low light data, moonrise/set, etc.) are required?	
Does the model or simulation require a spatially varying environment?	√
• The most basic environment is one that is homogeneous; i.e., is everywhere the same. Is this adequate to meet the M&S requirement?	
• An environment that is non-homogeneous is heterogeneous; i.e., it varies from place to place. Is this required by the model or simulation?	
• Does the model or simulation require a heterogeneous space environment?	
• Does the model or simulation require a heterogeneous atmospheric environment?	
• Does the model or simulation require a heterogeneous terrain environment?	
• Does the model or simulation require a heterogeneous ocean environment?	

Required Environment/Object Interactions Checklist	
• What is the spatial resolution required for changes in heterogeneous weather conditions in the model or simulation?	
Does the model or simulation require a temporally varying environment?	√
• A physical environment that is non-varying in time is static. Is this adequate to meet the M&S requirements?	
• A physical environment that varies across time is dynamic. Is this adequate to meet the M&S requirements?	
• Does the model or simulation require a dynamic space environment?	
• Does the model or simulation require a dynamic atmospheric environment?	
• Does the model or simulation require a dynamic terrain environment?	
• Does the model or simulation require a dynamic ocean environment?	
• What is the temporal resolution required for changes in dynamic environmental conditions in the model or simulation?	
Does the model or simulation require the inclusion of physical environmental processes?	√
• What global-scale physical processes are required by the model or simulation?	
• What synoptic scale physical processes are required by the model or simulation?	
• What mesoscale physical processes are required by the model or simulation?	
• What microscale physical processes are required by the model or simulation?	
• What molecular-level physical processes are required by the model or simulation?	
Does the model or simulation require that the environment affect mission space object characteristics and performance (C&P)?	√
• Must the space environment affect mission space object C&P?	
• Must the atmospheric environment affect mission space object C&P?	
• Must the terrain environment affect mission space object C&P?	
• Must the ocean environment affect mission space object C&P?	
Does the model or simulation require that mission space object characteristics and performance (C&P) impact (feed back into) the environment?	√
• Must mission space object C&P impact the space environment?	
• Must mission space object C&P impact the atmospheric environment?	
• Must mission space object C&P impact the terrain environment?	
• Must mission space object C&P impact the ocean environment?	

Required Environment/Object Interactions Checklist
*SCALES are defined as follows: • The warfighter's STRATEGIC scale is worldwide, equating to a global scale within the environmental representation. • The warfighter's THEATER TACTICAL scale is ocean-wide or continental, equating to a synoptic scale within the environmental representation. • The warfighter's MISSION SPACE scale ranges from 10-250 nm, equating to a mesoscale scale within the environmental representation. • The warfighter's MISSION SPACE ENTITY scale is on the scale of a platform or battalion, and equates to a microscale within the environmental representation. • The acquisition community's ENGINEERING-LEVEL scale is on the scale of an aircraft wing, an individual weapon, or an individual sensor or its component, and equates to a molecular scale (e.g., air flow around a wing or water flow around a propeller) within the environmental representation.

Federation Required Environment/Object Interactions Checklist	
• Does the federation require an environmental representation?	
• Are all federated M&S components implementing an environmental representation?	
• Are all federated M&S components implementing an environmental representation in common domains (space, atmosphere, terrain, ocean)?	
• Are all federated M&S components implementing the same spatial reference datum (horizontal and vertical)?	
• Are all federated M&S components implementing the same spatial coordinate system?	
• Are all federated M&S components implementing an environmental representation at the same spatial scale?	
• Are all federated M&S components implementing an environmental representation at the same temporal scale?	
• Are all federated M&S components implementing the same diurnal differentiation (between day and night)?	
• Are all federated M&S components implementing the same spatially varying environmental representation?	
• Are all federated M&S components implementing the same temporally varying environmental representation?	
• Do all federated M&S components include the same environmental processes?	
• Do all federated M&S components include the same environmental effects on mission space object C&P?	
• Do all federated M&S components include the same mission space object C&P feedback into the environmental representation?	

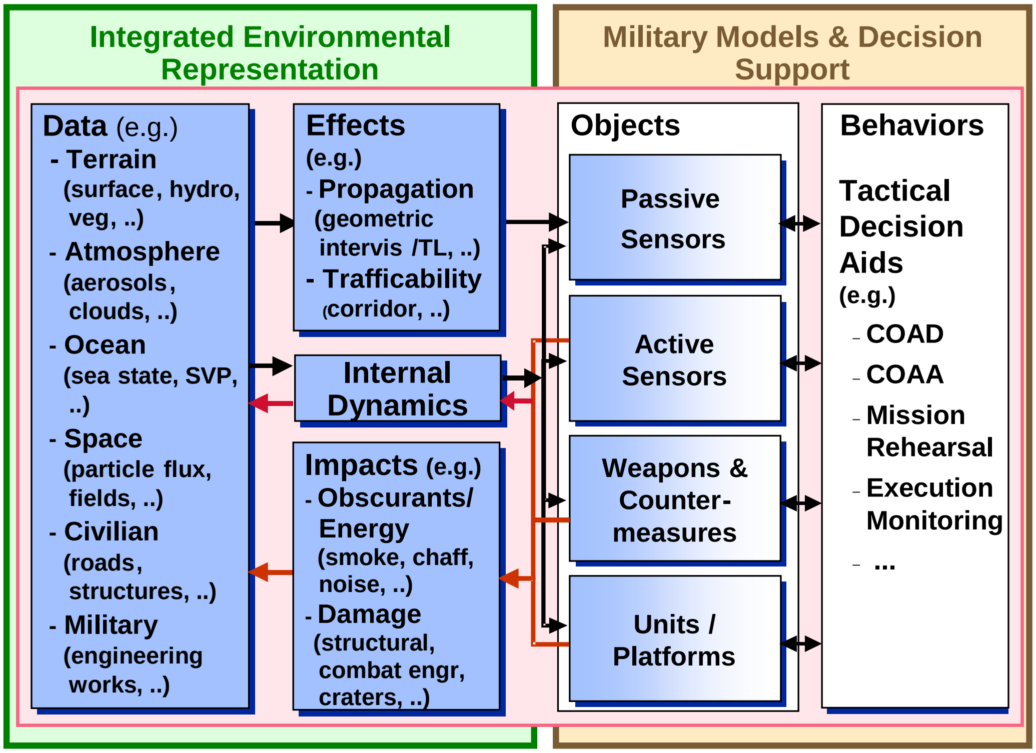
The information obtained using this checklist should present a reasonably comprehensive view of the environment needed for the intended application and can be used to shape the environmental representation used in the simulation.

From Interactions to Data: Identifying Specific Data Requirements

To support the simulation's ability to incorporate environmental effects on mission space objects and the objects' impacts on environmental conditions, the interactions need to be translated into specific requirements for environmental data and algorithms. This step may be (and possibly ***should*** be) performed iteratively. There are different methods available for identifying needed environmental data, including

- **Universal Joint Task List (UJTL)** -- First, the initial conditions (environmental, cultural, and military) under which each listed task is performed are identified (by the User and/or subject matter experts [SMEs][7]). Then, the tasks that the simulation is intended to perform are selected and the environmental conditions associated with each task are extracted [Chairman, CJCSM 3500.4B, 1999].
- **Synthetic Natural Environment (SNE) Conceptual Reference Model** -- This reference model, shown in the following figure [p. 15], portrays the information flow between raw environmental data elements and their end uses in depictions of mission space entity behaviors. It shows the breakdown between environmental conditions, impacts, and effects and their relationship to objects and behaviors. Using the set of desired environment/object interactions identified in the Required Environment/Object Interactions Checklist [p. 12], these behaviors would be the input into the Behavior box on the far right of the reference model in the figure. Tracing them to the left, the desired behaviors can be decomposed into performance calculations that determine actual behavior; from performance into the environment/entity interactions which control performance; and from the environment/entity interactions into the environmental data which are the determining factors of these interactions [Birkel, 1998].

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



SNE Conceptual Reference Model

Regardless of what method is used to develop the set of required environmental data, four types of data requirements should be included [Birkel, 1998]:

- mission space object descriptions, including capabilities and performance
- environmental algorithms which describe the interaction of the environment with these mission space objects, including the effects of the conditions on the objects and the impacts of the objects on the environment
- the data interface between environmental conditions, both analysis and forecast, and the larger set of mission space objects
- environmental conditions which are necessary components of the environmental algorithms, including related databases to be populated and maintained over the course of the simulation

As data and algorithm requirements are identified, an important associated task is to also identify the degree to which these requirements can be altered before the identified data or algorithm is no longer considered sufficient to meet the requirement. Environmental representations may need to be altered due to changes in the objectives or overall requirements of the intended application or due to hardware or software constraints, such as

- a program's selection of computer hardware processor speeds that restrict the ability of a computationally-intense algorithm to provide run-time calculation of effects
- storage limitations that restrict the performance of an algorithm or access to appropriate data
- decisions resolving resource/requirement imbalances that impact the ability of selected algorithms and data to meet stated requirements

Changes affecting the environmental representation may occur at any time during the life cycle of the simulation. Any alterations made should be carefully and consistently documented.

Incorporating Environmental Representation in the Simulation Conceptual Model

Once the required environmental data have been identified, they need to be associated with specific mission space objects and their behaviors in the simulation's conceptual model.[8] Here, the issues of fidelity and technical and substantive interoperability begin to be addressed in concrete ways, based upon the User's decision regarding the degree to which the real world needs to be represented for the intended use. For each mission space object identified in the simulation conceptual model, a series of technical questions should be asked [Youngblood, 2001]. Examples are listed in the following table.

Simulation Conceptual Model Environment/Object Issues
• Are the needed mission space objects available at the necessary level of detail?
• Do these mission space objects properly connect physically?
• Do these mission space objects exchange data in accordance with the Federation Object Model?
• What are the critical characteristics of the mission space entities that must be included in their related mission space objects?
• Do the mission space objects possess the attributes needed to support the simulation's (and, ultimately, the federation's) purpose?
• Can the mission space objects carry out the needed behaviors?
• Do these mission space objects logically work together, both within and across simulations?
• Are the algorithms used to compute environment/object interactions, both environmental effects and environmental impacts, consistent within and across simulations?

These questions are a reflection of some larger simulation issues that should also be considered:

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

- Do opposing force mission space objects have a legitimate chance to detect and engage each other? (Is the environment included in the two-way detection→engagement process? Are the same environmental conditions used for both sets of entities?)
- Do friendly force mission space objects fairly share mission space situation data? (Is the same set of environmental conditions used consistently within a common mission space situation?)
- Are some mission space objects affected, either favorably or adversely, by environmental conditions while others are not? (Is there a consistent “fair fight” environment across the mission space, whether it is a single or federated simulation?)
- Do any mission space objects use ground truth data to compute firing solutions? (Are these objects using ground truth environmental data rather than accessing the “perceived reality” environment of the simulation?) Is that acceptable?
- Do combat algorithms use unaccredited data values? (Are they using the proper environmental data from the appropriate sources?)
- Do combat algorithms use data values not empirically derived? (How are they deriving these values? Are the environmental data and assumptions consistent with those of other data used by the simulation and its objects?)
- Are combat algorithms consistently applied in all objects, both within and across simulations? (Is there a consistent “fair fight” environment across the mission space?)

Each of the environmental data requirements should be discretely associated with the specific mission space objects and interactions that will use them. Some of these associations have been established for baseline object models in the Functional Description of the Mission Space (FDMS)[9] object set; however, others may have to be added [DMSO, FDMS]. Although all objects and interactions do not need to be represented at the same level of resolution, interactions between objects need to be scientifically accurate to the degree required by the application requirements and assumptions, and must properly reflect the mission space objectives.

Incorporating Environmental Representation in the Simulation Design

The design of the environmental representation should be viewed from the perspective of the complete simulation and its set of objects. In the real world, the natural environment does not exist as a separate, stand-alone “thing” which occasionally “touches” a mission space entity with its temperature or precipitation characteristics. Instead, it is an all-encompassing background that interacts with each and every entity that exists. Awareness of the need to consider the effects of the physical environment

[9] The FDMS was formerly known as the Conceptual Model of the Mission Space (CMMS).

on each mission space object will help establish the “level playing field” so essential for fair play during simulation implementation.

The following environmental models should be included in the simulation design [DMSO, FDMS]:

- **state models**, which describe measurable characteristics of the physical environment at a given point
- **effect models**, which describe the results of the direct influence of the environment on mission space objects
- **impact models**, which describe the direct influence of mission space objects on the environment
- **internal dynamics models**, which address the evolution of the environment in time and in space as determined by non-military factors (e.g. a volcanic eruption)

The development of environmental models should parallel that of mission space objects (e.g., mission space entity component models and entity behavior models) in order to maintain a consistent level of fidelity across the desired simulation implementation.

- **object component models** consist of those algorithms used to model mission space entities, both persons and equipment, which create the mission space objects whose characteristics and performance are subject to effects by the environment
- **object behavior models** consist of those algorithms used to model how mission space objects are employed in response to simulation conditions, some of which may be environmentally generated

The environmental focus in the simulation conceptual model is on specific environmental data and the specific mission space entity interactions that require them. In simulation design, as the focus moves beyond specific entities, the requirements of contextual interoperability within and across simulations become paramount. For the natural environment, these requirements include:

- consistent, physically accurate depictions of environmental entities[10] and events within one or more of the four environmental domains (space, atmosphere, terrain, and ocean) and across domain boundaries
- coherent physical, temporal, and spatial relationships between the physical environment domains, the mission space objects, and the energy (acoustic, electromagnetic) emitted into the environment by mission space objects

[10] This assumes that environmental entities can be modeled discretely. In many cases, however, raster or gridded numerical data encompass multiple environmental entities in a single depiction, which need to be internally consistent to meet the requirement stated here.

- consistent, correlated depiction of both visual and non-visual aspects of the environment (including buildings, terrain features, infrared radiation, etc.)
- consistent (but not necessarily identical) depiction of the three-dimensional location of mission space objects, so that a proper three-dimensional correlation of objects occurs within and across simulations
- consistent (but not necessarily identical) depiction of the physical, temporal, and spatial portrayal of environment/entity interactions (conditions, effects, and impacts) within and across simulations

Resources and Support

Subject Matter Experts

A significant resource for environmental support are the SMEs who staff the offices of the various M&S Executive Agents (MSEAs) for the Natural Environment (i.e., Air and Space Natural Environment [ASNE], Terrain, and Ocean) and the Defense Modeling and Simulation Office (DMSO) Environmental Representation Technology Area. These SMEs are available to assist with

- identifying and refining requirements for environmental data and algorithms
- identifying appropriate sources for environmental data and algorithms
- planning the simulation development or modification
- planning the V&V effort

Because of their familiarity with available environmental data and their production processes, these SMEs should be consulted, at a minimum, for advice on environmental data issues, including:

- appropriate data sources (e.g., Authoritative Data Sources [DMSO, ADS], DoD MSEA Integrated Natural Environment Authoritative Representation Process [INEARP])
- necessary metadata
- data consistency, which includes lexical (definition), syntactic (format), and semantic (usage)
- appropriate data transformations, both spatial (geo-referencing) and syntactic (format)

Environmental Data Sources

User identification of environmental data sources almost always begins with identification of an environmental data producer associated with the type of data required. Within the DoD, major environmental data producers are the Air Force

Combat Climatology Center, the Fleet Numerical Meteorology and Oceanography Center, the National Geospatial-Intelligence Agency, and the Naval Oceanographic Office. DoD MSEAs work closely with these producers to ensure optimum support to meet required M&S environmental data capabilities, and they should be viewed as key resources to assist simulation developers in identifying and acquiring environmental data for use in M&S applications.

Optimizing support requires establishing a balance between what the simulation requires and what the producer can provide. Although a vast amount of environmental data exists within archives, either as raw data, integrated databases, or climatology products for varying periods, simulations often require data that must be developed as new products from archived data or produced new by existing environmental models or database generation processes.

The Master Environmental Library (MEL) System, which is a “library of libraries,” connects a number of environmental data producers, including those named, into a “seamless” network to provide ease of search, identification, location, and procurement of needed environmental data products. One of the libraries accessible through the MEL System is the Navy’s Oceanographic and Atmospheric Master Library [DMSO, OAML]. Others include the vast climatology archives of the U.S. National Weather Service, available through the Air Force Combat Climatology Center and the geospatial data archive of the National Geospatial-Intelligence Agency.

If the simulation requires production of a specific, environmental condition driven scenario, the Environmental Scenario Generator (ESG), which is linked to the MEL System, becomes a key resource to the developer. In the ESG, the user can identify specific required atmospheric conditions—the ESG will search archived data for “matching” weather scenarios and, if present, provide the related data to the user. If no matches exist in the archive, the ESG will initiate and monitor production of a specific environmental scenario for simulation use.

Once the needed environmental data are obtained for the simulation, simulation developers must be extremely careful when identifying some data as “ground truth” and others as “changing environmental conditions,” specifically weather effects and impacts, simply because “ground truth” is, itself, a simulated version of the “real world.” The development team must be prepared to examine all assumptions made in developing, extracting, and implementing both types of environmental data, as well as verify the consistency of those assumptions across the entire simulation mission space, including temporal and spatial dimensions. While this can be challenging to the development team, the checklists presented earlier should help to identify these assumptions and facilitate their inclusion and documentation in the conceptual model.

MEL metadata were developed for the particular purpose of simplifying the processes for data selection and examination of product assumptions. Included are an explicit description of the Library resource and a list of data elements contained in the resource, production data quality information developed in accordance with recommendations from the M&S community, as well as information about implementation capabilities and limitations of the resource, and assumptions incorporated into resource development [DMSO, 1998]. Because it is not guaranteed that all Library resources will have complete metadata, the authority of these resources will be indicated in accordance with the categories established in the Authoritative Data Sources project [DMSO, ADS].

A common error made by environmental data users is to assume that a dataset obtained from an "official" or "authoritative" source is automatically ***appropriate*** for the intended use. Such is not the case. Appropriateness is an essential element in ensuring proper data support to a simulation. Appropriateness is determined, not only by the quality of the production process and related data collection process(es), but also by the quality of the data themselves and the consistency of assumptions between the data production processes and the simulation requirements. MSEA assistance may be necessary to help ensure selection of the most appropriate environmental product from the large number of "authoritative" products available.

Data products provided by authoritative sources, including computer renditions of standard algorithms, typically undergo a rigorous scientific verification and validation process. Such a process assures the simulation developer that the product being received is based on good science and the highest quality input data available, and that it is fully conformant to the published product or model specifications. This should fully satisfy any verification requirement established by the simulation for the particular data product.

Tools

Because of their significance to any simulation, there are a number of tools and resources available to help address data consistency and data transformation issues, such as

- set of international standards being developed by the Simulated Environment Data Representation and Interchange Specification (SEDRIS) program to facilitate interoperability of environmental data [DMSO, SEDRIS]
- Environmental Data Coding Specification (EDCS), which ensures lexical consistency by standardizing the definitions associated with a given label and syntactic consistency by providing standard formats for textual and numeric values associated with specific environmental data codes
- SEDRIS Data Representation Model (SDRM), which supports semantic consistency by providing business rules for the creation and association of environmental objects, including their classification and attribution
- Spatial Reference Model (SRM), which enables a developer to geospatially transform multiple databases into a common georeference frame (on the earth or any other planet, as well as the sun or any other star)

Transformation issues are not limited to the spatial distribution of data. They also involve the ability of two or more databases to interact with each other, whether such occurs through data exchange, data merge, or data update. Such data interactions require all three aspects of data consistency; thus, any tool used to facilitate these interactions needs to able to support all three aspects of data consistency to the extent required by each interaction. One tool that accommodates this is the SEDRIS Read/Write Application Program Interface (API), used in conjunction with the SEDRIS Transmittal Format (STF), which provides for the translation of multiple native-format databases into STF to enable the comparison, merging, update, and exchange of databases from different sources[11]

Both the availability and appropriateness of environmental data and models/algorithms should be considered. In some cases, the necessary data may not be available. In others, data may be available but the associated metadata may not provide sufficient information to support their use in the intended application. Finally, the data may need to be transformed in order to be used in the simulation.

> Example:
> Data are often transformed in georeferencing to resolve problems with data consistency.

If problems arise regarding the acquisition or implementation of needed environmental data and models/algorithms, one or more of the tools listed above may be used to help resolve them. However, if the problems persist, the environmental representation requirements may need to be revisited or the simulation design reviewed.

Designing Environment/Object Interactions: Challenges and Resources

There are a number of specific challenges associated with capturing and implementing environment/mission space entity interactions in simulation mission space objects. These challenges, identified in the table on Challenges of Environmental Effects and Impacts [p. 7], can be managed through the use of the resources identified in the following tables:

Interaction Challenges and Resources to Address Them		
Challenges	**Related Challenges**	**Resources**
Trafficability Interactions		
• Proper correlation of mission space object with surrounding environment	• coordinate transformations • use of appropriate sources of environmental data • fusion of environmental	• Integrated Natural Environment Authoritative Representation Process • Environmental Scenario Generator • Spatial Reference Model

[11]Use of this translation capability also transforms proprietary source data to an open format, enabling use of various data sources to update existing data, reducing source obsolescence and data maintenance costs, and eliminating incompatibility obstacles to interoperability.

Interaction Challenges and Resources to Address Them		
Challenges	**Related Challenges**	**Resources**
• Consistency of effects and impacts across environmental domains	data and mission space object • determination and maintenance of necessary data quality	• Environmental Data Coding Specification • SEDRIS Transmittal Format; SEDRIS Data Representation Model • Master Environmental Library with data quality metadata
Sensors Interactions		
• Proper correlation of mission space object with surrounding environment • Proper correlation of energy propagation path with related environment	• coordinate transformation • fusion of environment with mission space objects and their sensors' emitted energy • use of appropriate data sources • use of appropriate environmental effects models • determination and maintenance of necessary data quality	• Integrated Natural Environment Authoritative Representation Process • Environmental Scenario Generator • Spatial Reference Model • Environmental Data Coding Specification • SEDRIS Transmittal Format • SEDRIS Data Representation Model • Master Environmental Library (with data quality metadata) • Oceanographic and Atmospheric Master Library (OAML)[12] energy propagation algorithms and related databases
Intervisibility Interactions		
• Fusion of multiple types of environmental and mission space information • Precise positioning of mission space objects and features of the complete environment between the mission space objects	• coordinate transformation • fusion of environment with mission space objects and their sensors' emitted energy • use of appropriate data sources • use of appropriate environmental effects models • determination and maintenance of necessary data quality	• Integrated Natural Environment Authoritative Representation Process • Environmental Scenario Generator • Spatial Reference Model • Environmental Data Coding Specification • SEDRIS Transmittal Format • SEDRIS Data Representation Model • Master Environmental Library (with data quality metadata) • Oceanographic and Atmospheric Master Library (OAML) energy propagation algorithms and related databases
Weapons Interactions		
• Fusion of multiple types of environmental and cultural feature	• use of physically-consistent multi-domain environmental data	• Integrated Natural Environment Authoritative Representation Process • Environmental Scenario Generator

[12]The Oceanographic and Atmospheric Master Library (OAML) is the United States Navy's standard source of scientifically valid oceanographic and atmospheric algorithms and databases, including energy propagation algorithms that incorporate oceanographic and atmospheric effects. OAML is one of the core libraries intended to be available to users through the Master Environmental Library.

Interaction Challenges and Resources to Address Them		
Challenges	**Related Challenges**	**Resources**
data • Precise positioning of targets, detonation, and damage pattern	• coordinate transformations • precise fusion of high quality targeting information • fusion of targeting and battle damage assessment/information	• Spatial Reference Model • Environmental Data Coding Specification • SEDRIS Transmittal Format • SEDRIS Data Representation Model • Master Environmental Library (with data quality metadata)
Infrastructure Interactions		
• Fusion of multiple types of environmental and cultural feature data • Precise positioning of environmental phenomena and infrastructure features	• use of physically-consistent multi-domain environmental data • coordinate transformations • fusion of environmental conditions and phenomena with positions and status of facilities, buildings, networks, and features	• Integrated Natural Environment Authoritative Representation Process • Environmental Scenario Generator • Master Environmental Library with data quality metadata • Spatial Reference Model • Environmental Data Coding Specification • SEDRIS Transmittal Format • SEDRIS Data Representation Model

Cross-Category Challenges	
Related Challenges	**Resources to Address Challenges**
Consistent application of the environment across all mission space objects in the simulation (and across the federation, when applicable)	
• ability to identify, verify, and validate embedded environmental effects models in mission space object models	• Environment Conceptual Reference Model • Environmental Subject Matter Experts
Physical consistency of the environment within an environmental domain and across domain boundaries	
• identification of appropriate data sources • maintenance of required data quality	• Environment Concept Model • Environmental Subject Matter Experts • Environmental Scenario Generator • Master Environmental Library with data quality metadata • Integrated Natural Environment Authoritative Representation Process
Physical consistency of the environment when the environmental transition (spin-up) time is compressed or eliminated	
	• Environmental Subject Matter Experts • Environmental Scenario Generator • Integrated Natural Environment Authoritative Representation Process

Verification and Validation

Because the environmental representations and behaviors are part of the overall simulation, their verification and validation are part of the overall V&V effort. This section discusses those aspects of the overall V&V effort that focus on environmental representation issues. Information about the overall verification and validation process can be found in the core documents on the V&V Agent's role.[13]

Environmental Verification

Timely verification of environmental design decisions (e.g., during the development or modification of the simulation design) can minimize risk and solve problems before implementation decisions limit options. During the verification of environmental conditions, the actual environmental information to be included in the simulation is examined, including environmental algorithms and data that are available in either their native or a transformed format. Verification is focused on the appropriate use and transformation of the correct data elements—in their lexical, syntactic, and semantic forms. The actual data content, or instance data, may vary from implementation run to implementation run without additional verification, but changes to the data formats, structures, and related algorithms would require such.

If an algorithm is to be used in native format, the individual input data elements should be examined for lexical, syntactic, and semantic consistency across their simulation usage.

> Example:
>
> The calculation of sound speed in the ocean involves the use of seawater depth, temperature, and salinity. If temperature is calculated in Centigrade degrees, but then exchanged with an air/ocean algorithm using temperature in Fahrenheit degrees, there is a conversion involved that may prove lossy (affects lexical and syntactic consistency). Furthermore, if the ocean sound speed calculation identifies "water surface" at the lowest point of the waves on the water surface and the air/ocean algorithm identifies "water surface" at the maximum height of sea spray off the wave crests, there is a semantic inconsistency that may cause errors in simulation behavior and results. To perform this examination, the simulation developers must have a good lexical, syntactic, and semantic understanding of the data in the various databases used across the simulation as well as of the algorithms that will be applied to those data.

If an algorithm needs to be revised or reformatted for use in the simulation, verification helps to identify and limit, if not eliminate, errors introduced by the revision process (e.g., changes in scientific method(s) of calculation, variations in programming

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[13] See the core documents on V&V Agent's Role in the VV&A of Legacy Simulations and V&V Agent's Role in the VV&A of New Simulations for additional information.

languages and related functions, integration of the algorithm into applications that differ from those for which the algorithm was originally designed, typographical errors).

The data to be used as input in each algorithm should be checked to ensure they are appropriate and authoritative. When using standard environmental data products[14], no additional verification is required on the provided data. However, if these data are used as input to an algorithm, the results of the algorithm should be verified to ensure they continue to be appropriate. If the data are used in a transformed format, they need to be additionally verified to ensure that the transformation process has not changed the value of the original data in any significant way. (The definition of “significant” is deliberately left to the Developer and to the User, since its meaning is relative to the needs of the application and to the assumptions incorporated into the simulation. Such a definition, nevertheless, should be clearly documented and included in the verification documentation.)

When data transformations are involved, it is not usually necessary (and certainly not cost-effective!) to re-validate transformation methods that have already been scientifically verified and validated, such as standard environmental algorithms in the OAML and those incorporated into SEDRIS products (provided that no changes are made to the ingested data). Documentation of the assumptions contained in validation results of each method should suffice. It is important to note that, while this satisfies validation requirements, it does NOT satisfy verification requirements for the data transformed by these methods.

The verification of effect and impact environment/object interactions should focus on the calculations of these interactions. While there are often several acceptable calculation methods, the assumptions integral to each may be critical determinants of suitability/unsuitability. This verification effort should include

- identification of algorithm and data sources
- assumptions built into calculation algorithms
- assumptions made to tailor calculation results to the implementation requirements of the simulation

Look-up tables can present many challenges to the verification process because embedded algorithms need to be extracted and viewed—and simulation implementation requirements may necessitate multiple layers of embedded calculations. It is necessary to unwrap look-up tables through all intermediate algorithms until their foundational data can be identified. If a “previously verified and validated” table is used, no additional verification is necessary provided sufficient documentation is present to fully understand the product specifications of the table. In this case, also, it is important to note that,

[14] This requires that the product has been scientifically verified and validated in its exact production process, using a statistically significant set of product runs. The same applies to product options, which require separate examination within the context of their production process variations.

while this satisfies verification requirements, it does NOT satisfy validation requirements for look-up tables.

Environmental Validation

The goal of the environmental portion of the validation effort is to determine if the environmental representations and interactions adequately address the needs of the intended application: Are the representations complete and appropriate? Do the environmental objects and mission space objects perform correctly based on the requirements and constraints of the intended use? The validation of mission space objects should begin while they are being built. When they are complete they should be validated both as stand-alone objects (do they possess the same characteristics and performance as the real-world system equivalent?) and in the context of the environment/object interactions in which they are expected to be involved(are those characteristics and performance affected by the environment in the same way as real-world systems are affected?). This involves an examination of the environmental conditions that comprise the context for the mission space object, those that affect the mission space object, and those that change as a result of impacts on the environment by the mission space object.

The environmental representation validation effort should determine

- if the mission space objects are accurate and reasonable representations within the physical processes of the environment and within their own physical (behavior) processes as defined by the intended application
- if the mission space objects exist appropriately within the realm of known occurrences of environmental effects including mission space entity feedback into the environment
- if the mission space object behaviors and the results of their interactions with the environment are reasonable and consistent across the domains associated with the intended application
- if the interactions between mission space objects are appropriate and consistent across the environmental domains defined by the intended application
- if related environmental processes can correctly affect mission space objects and their interactions in both time and space (e.g., the two-way transmission of emitted energy in the acoustic and electromagnetic—including visual—spectrum)

Because the consistency of environment/object interactions is essential for establishing a “level playing field” or achieving substantive interoperability, the set of interfaces through which environmental information will pass should be evaluated to ensure that the environmental information exchanged anywhere within a simulation or across simulation boundaries is not altered by its movement through a database, program, or communication interface.

When environmental products, transformation methods, or look-up tables are used, they must undergo a separate validation step before being included in the validation of any interaction. Because the development of products, methods, and look-up tables necessarily involve using one or more assumptions to replicate the "real world," these assumptions must be examined within the context of the intended use. Each assumption must be determined as consistent with others in the context of the simulation and its implementation of the product, method, or look-up table. In some cases, necessary inconsistencies will occur—these must be documented for later evaluation of their effects on simulation results. Once this validation occurs, then validation of any related interactions can be performed.

Algorithms that ingest or produce environmental information should be validated to ensure they are implemented properly so that the results of applying the algorithm are reasonable and consistent with real-world natural environment processes as defined by the intended use.

Validation Data

One of the major challenges to any validation effort is ensuring that appropriate validation (testing) data are available. Results validation normally involves comparison of the results of a simulation to the referent (a codified body of knowledge about the thing being simulated based on M&S requirements [RPG Glossary]) and data describing this referent needs to be identified and collected or developed.[15] For the environmental portion of a validation effort this will involve acquiring appropriate environmental data and data describing environmental objects and environment/object interactions.

Validation data can be generated a number of ways, including real-world empirical data (e.g., physical measurements, test range results, historical records), appropriate simulation results, test results, regression testing, and SMEs (e.g., objective validation, face validation). Regardless of how validation data are generated, it is essential that they be obtained from reliable sources.

- DoD environmental data producers conduct extensive algorithmic and data validation before releasing environmental algorithms, databases, and composite data products. Such information is extremely useful in ensuring correct installation, implementation, and interpretation of the supplied products.
- Accreditation agencies can supply data that were used previously in the same or similar simulations; such data and pertinent information about their usage should be available as part of the accreditation package.
- The simulation developer can supply data and archived results from the simulation development and testing effort.

[15]See the special topics, Data V&V for Legacy Simulations and Data V&V for New Simulations, and the reference documents, M&S Data Concepts and Terms and Data V&V White Paper, for additional information.

- The owner and previous users of a simulation can supply data and archived results from previous applications.
- Research organizations develop and test databases under a variety of laboratory and real-world conditions.

In all situations, care should be taken to ensure that only appropriate data--data developed and used with consistent assumptions and constraints for similar purposes--are selected.

Summary

This document has discussed the benefits and challenges of including an environmental representation in a simulation and has presented ways of developing the appropriate foundation for verification and validation of that representation. It examined the simulation development process and identified tasks that assimilate the natural environment in that process, focusing not only on the environmental representation itself but also on the interaction between simulation mission space objects and the represented environment.

The document identified two principal parts of an environment/entity feedback loop as organizing principles: the environmental effects which arise from interaction of environmental conditions and mission space entities and the impacts on the environment caused by mission space entities and their environmental effects. It also established five different categories of mission space object/environment interactions and used them to outline the general and specific challenges, as well as resources, involved in integrating them into a simulation.

Finally, the document discussed some of the major environment-related V&V issues and presented a look toward the future in the development of additional resources for use by simulation developers in establishing environmental foundations for verification and validation.

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

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select menu, *RPG Reference Documents*, select Item, "Data V&V Tiger Team White Paper"

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