CONSISTENCY AS A FIRST STEP IN MOVING TOWARD A COMMON SYNTHETIC NATURAL ENVIRONMENT STANDARD

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ABSTRACT: *The models and simulations being incorporated into today's training systems are becoming more complicated and expansive at all levels from the individual warfighter through the field commander. Training systems will encompass a battlespace that includes all aspects of the natural environment encountered in space, air, land and at sea warfare. Traditionally, each simulation has developed it's own independent environmental representations, with little consideration of consistency across an entire federation. This paper presents an approach for developing a synthetic common natural environmental standard that can be applied across an entire federation. A common natural environment is defined as consisting of the databases and models that transform the databases to multiple levels of fidelity and resolution. The common environment is derived from the Synthetic Natural Environment Representation efforts which have been adopted by Maritime Virtual Environment Data Specification (MARVEDS) working group as our model for the development of a synthetic natural environment specification. We will show that to qualify as common, all federates must use the same underlying databases and must use the same set of models and algorithms to achieve any particular level of resolution. Implicitly, the models and algorithms used to transform from a higher resolution to a lower resolution must be consistent with physical constraints and the processing used by the tactical equipment. Efforts ongoing in the Battleforce Tactical Trainer (BFTT) and the Integrated Ship-Defense (ISD) programs will be used to illustrate the need for the common environmental standard*

AUTHORS BIOGRAPHIES

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PURPOSE

Consistency of the environment is a question often raised when models and simulations are brought together to form a federation whether for training, engineering analysis, design or other purpose.
This paper puts forth several rules and an associated process that can be applied in developing a synthetic environment that is consistent within and across domains both horizontally and vertically. These rules and the associated process support the aggregation of environmental information and support procedures for dynamically changing the environmental characteristics, introducing features, and for handling effects and impacts. The practical application of this process is illustrated by a use case conducted by the Navy's MARVEDS coalition for the Integrated Ship Self Defense Program (ISD) and the Battle Force Tactical Training Program.

1.0 INTRODUCTION & BACKGROUND

Today the majority of existing M&S systems have been developed to satisfy particular sensors, weapons systems, design, testing and training needs within their particular communities. Several joint simulations, JSIMS (http://www.jsims.mil/), (Tier I through Tier III training), JWARS (http://www.dtic.mil/jwars/), (joint theater warfare analysis), JMASS (http://www.jmass.wpafb.af.mil/), (simulation support environment) are being developed but are currently in the minority compared to the hundreds of individual Service simulations. There are simulations that represent the complete training spectrum from individual Tier I training to campaign level Tier III training. A common requirement of all these simulations is the need for a synthetic environment.

As the implementation of the High Level Architecture (HLA) is becoming more widespread individual simulation developers and users are asking the question- Now that I am HLA compliant, what other simulations should I be federating (connecting) with? This question resolves into "at what meaningful level of interoperability can two or more federates be integrated together?" Do the federates view the mission space consistently to achieve a common representation of that mission space in a data model.

When designing a simulation from scratch those issues can more easily be decided based on the simulation's purpose. However, if the simulation is integrating several legacy simulations systems into a federation a considerable effort is expended resolving the mission space into interoperable levels of resolution for interaction and data exchange.

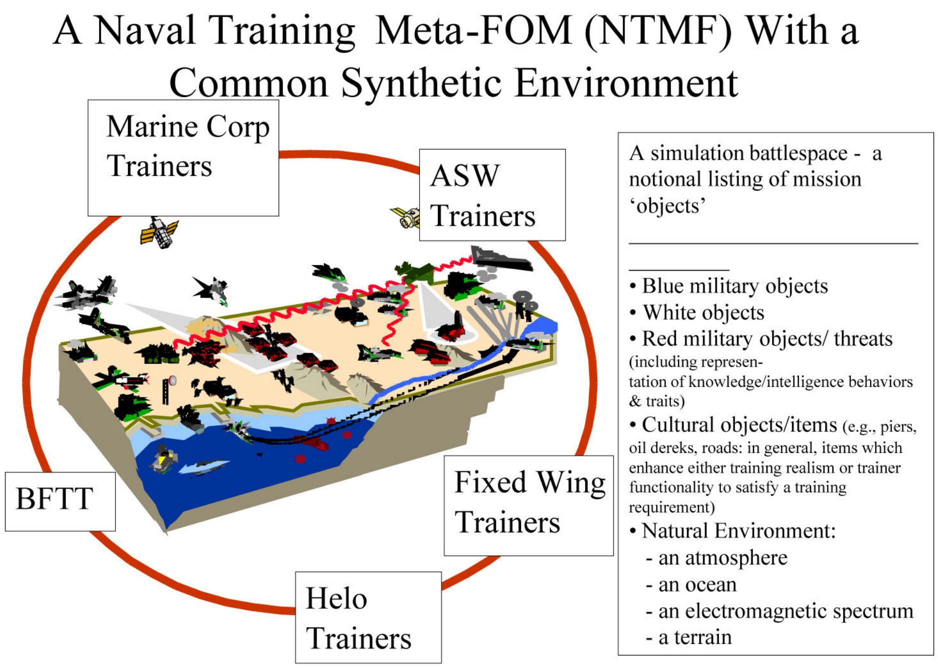

Figure 1. Navy training Meta Federation Object Model (FOM) (NTMF)

Figure 1 shows one particular federation concept consisting of several legacy simulations (federates) being combined into a large (meta) training federation, this meta FOM could provide the capability to perform a wide range of training encompassing multiple levels of resolution and aggregation. However, within this federation, each federate has been specialized for a particular purpose, and each has therefore developed its own representation of the synthetic environment.

To affect this federation concept into a meaningful one, the models within each simulation must have the same common view of the environment as the users of the models and simulations. The representation of the natural and physical environment in these models and simulations must be consistent. The data representing the domains of terrain, ocean, atmosphere and space must be physically consistent within each domain and across-domains. The environmental representations used by different simulations must be consistent if these simulations are to be fully interoperable and train at all levels of aggregation. Simply expressed, a consistent environmental representation means, "everyone plays on the same day". More rigorously, consistent natural environments provide representations that are valid to a chosen resolution, and are spatially, temporally and spectrally continuous. Because there are no guidelines or standards on how to represent the mission space into bounded levels of aggregation or resolution or fidelity for ease of federation assembly, it presents a significant time consuming problem to the federation engineer to provide a meaningful federation of legacy federates.

DMSO and other DoD agencies, through several programs, are addressing the importance of data consistency and data standards. Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) is leading the effort to standardize meteorological and oceanographic data elements. Through the Joint Meteorology & Oceanography (METOC) Conceptual Data Model, all meteorological and oceanographic data elements required by operational forces are being standardized in the Defense Data Dictionary System (DDDS) (http://ads.msrr.dmso.mil/). The Modeling And Simulation Resource Repository (MSRR) provides access to M&S developed products. The Master Environmental Library (MEL), (http://mel.dmso.mil/) is part of the MSRR and provides access to environmental data and models. Synthetic Environment Data Representation Interchange Specification (SEDRIS), (http://www.sedris.org/) is being developed to facilitate data transfer between suppliers and users of data.

1.1 The integrated natural environment

The natural environment may be broadly categorized by four domains: terrain, atmosphere, space and ocean. The interfaces between these domains are critical. The environmental data contained within these domains tend to be domain specific, with each having different parameters of significance for modeling physical phenomena. Temporal and spatial scales of significance for modeling vary across domains as well.

Representations of the natural environment are available to the simulation developer in the form of models and data. An environmental reference model, figure 2, [1] is currently proceeding through the Simulation Interoperability Standards Organization (SISO) standards process.

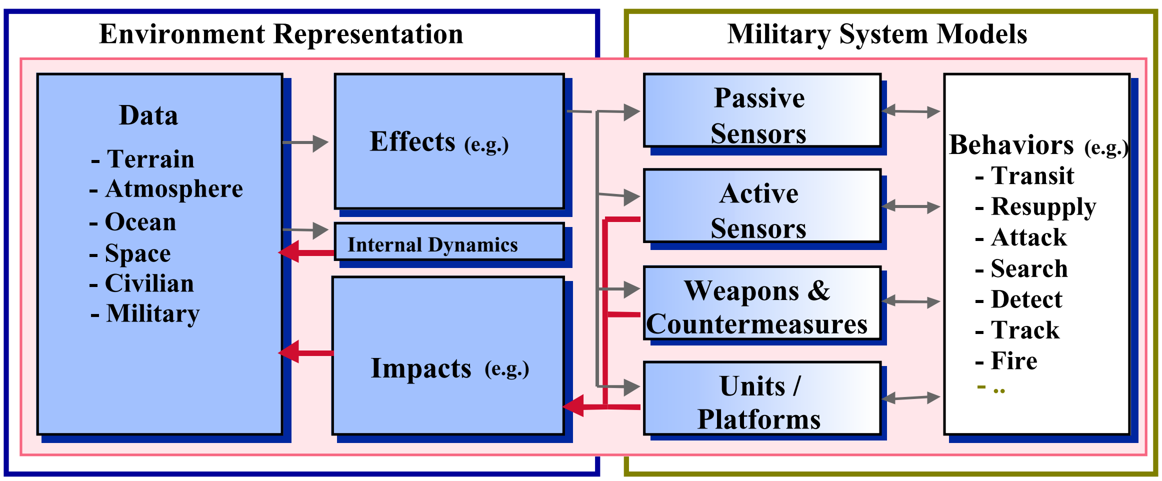

Figure 2. Environment Reference Model

As shown in figure 2 interactions of the environment with itself and with other objects must be considered. Enhancements to the representation to include high resolution or in-situ data are called environmental features. Environmental effects are the changes in the state or behavior of the environment that are a result of the environment reacting with itself and participating entities. Environmental effects are seen when rain falls on the ocean surface increasing the level of ambient noise, waves releasing salt spray into the air affecting visibility, and rain falling on the terrain changing the temperature through evaporation and making surfaces wet. Environmental impacts are the changes in the state or behavior of the environment that are a result of introduced objects reacting with the environment. Examples of environmental impacts include jet aircraft contrails, the wakes left by ships traveling through water, tanks traveling across mud leaving tracks, and exploding shells that leave craters in the terrain and release dust into the air, obscuring visibility. The last concept to be introduced is fidelity. The term “fidelity” is often used in an ambiguous way. Efforts are currently underway within the M&S community to better define this term [2]. As an example degrees of fidelity are often used to refer to levels of resolution, e.g. a training federate has one level of resolution and a Test and Evaluation federate has a higher level of resolution or higher degree of fidelity in its object models. However, a fuller definition of fidelity also encompasses accuracy in addition to resolution, i.e. an assessment of how closely the real world behaviors are modeled.

1.2 The status today

No detailed baseline synthetic environmental standard or specification describing how to develop (process) or what should be contained within the synthetic environment exists for use by M&S applications within their individual domains, much less for the complete integrated environment. The Maritime Virtual Environmental Data Specification (MARVEDS) initiative, described later in this paper, is addressing the development of a synthetic natural environment specification.

Programs attempting to reuse legacy models and simulations to create new federations, as well as those starting from scratch often do not have the cross domain subject matter experts available nor adequate financial resources to develop a consistent environmental representation. Often, they attempt to take what is available and make the best of it. This gets confused further when multiple choices are available for the same type of data, or when missing data needs to be 'filled in'. Clearly the results of simulation based on a physically inconsistent view of the environment are of questionable validity and do not warrant the investment. The results of two simulations cannot be compared nor can they effectively interoperate when the environmental data has been independently developed for each simulation and where different physical inconsistencies are present between the simulations.

1.3 Developing an Environmental Representation

The role of the simulation engineer must focus on the attainment of an integrated, consistent environmental representation within a federation. Regrettably a limited number of tools are now in place to assist in this development. The Master Environmental Library (MEL) is available as an access path, and SEDRIS has been defined to facilitate the transfer and use of the data. This paper will put forth several rules that can be applied in developing a synthetic environment that is consistent within and across domains, supports the aggregation of environmental information and supports procedures for dynamically changing the environmental characteristics, introducing features, and for handling effects and impacts.

1.4 Risks of Not Providing a Baseline Integrated Representation of the Natural Environment

The risks of not having a consistent environmental representation are apparent. We have seen simple examples (e.g. a distributed simulation where the tank hid behind trees to avoid being blown up by the helicopter, however the helicopter fired successfully upon the tank since the helicopter's environment didn't have the same stand of trees). A much more subtle problem is the modeling of wave action in the ocean due to winds that failed to take into account proper use of tidal information and currents, resulting in a physically impossible representation of wave behavior.

Modeling and simulation results based on inconsistent views of the natural environment should not be compared. Unfortunately, comparisons are made every day between simulations that have differing environmental representations. Developing a consistent representation of the environment is a complex problem requiring the efforts of a team consisting of subject matter experts in every domain, simulation engineers, model developers and systems engineers.

2.0 WHEN AND WHY CONSISTENCY MATTERS

In the introduction we have tried to demonstrate the importance of consistency. Here we continue the discussion in a more detailed manner as we lay the groundwork for presenting a set of rules and a process to assist in insuring consistency with a federation.

Consistency matters whenever two or more sensors (or entities) can observe the same parameter at the same time. At the same time is taken here to include any interpolation or extrapolation (e.g., dead reckoning) of the parameter. In addition, the sensors must communicate their understanding of the parameter's value. This communication can be direct, as might occur if one simulation passes off or reports the parameter to other observers, or it may be indirect. An example of indirect communication of a parameter between federates is the position of a soldier relative to cover. If one simulation places the soldier behind the cover and the other does not they have indirectly mis-communicated the soldier's relative position.

From the training viewpoint consistency is important because its lack introduces artifacts and anomalies into the training scenario. The most obvious anomalies are those that provide an artificial advantage to one or more participants. This is usually referred to as the "fair fight" problem. Inconsistency can introduce subtle biases, relative performance errors or outright crashes of the simulation. While consistency is not sufficient for a meaningful training exercise or simulation it is usually necessary. When consistency is lacking the participants usually perceive the training exercise to be degraded. (They may not notice the inconsistency and come to incorrect conclusions.)

In general, two measurements are said to be consistent if they agree to within the combined statistical accuracy of the two observers. That is, if it is reasonable to assume that the two measurements were the same but drawn from the statistical distributions that represent the sensors respective measurement accuracies. When using this approach for aggregations the consistency measurement will often be moved from the actual parameters to statistics of the parameters.

It is important to remember that just passing the proper data is not enough to insure consistency, it is necessary but not sufficient. How the data is used within the model or simulation must be considered. If a sound velocity profile is sent to two simulations one using a parabolic equation to determine propagation loss and the other a normal mode model, the resulting propagation loss may vary significantly. This paper will not attempt to select or promote any particular statistical measure for quantifying consistency. There are many to choose from. What we will do is put forth a set of rules for determining consistency, and an example of how these rules were used by the MARVEDS coalition to determine the consistency within an engineering federation.

3.0 GENERAL RULES FOR ACHIEVING CONSISTENCY

Consider a situation where at least two sensors are observing the same parameter at the same time. These observations may be either direct or indirect. A direct observation is one where an environmental parameter is measured by both federates at the same time. An example might be ambient temperature. An indirect observation is one where the two federates measure some other parameter that depends on an environmental parameter. An example of an indirect observation might be RADAR detection range, which depends on temperature and humidity profiles.

Begin with the assumption that a base environmental representation exists. In order to achieve consistent, multi-level environmental representations they must be derived directly or indirectly from the base environmental representation. This is a fairly stringent requirement. The situation is complicated by the fact that we must admit the possibility of a virtual base environmental representation. That is the base environmental representation may not ever be instantiated in the federation, but is still used as a reference against which derived representation are checked for consistency.

Figure 3 illustrates the types of environmental representations that are commonly encountered. The letter "T" is used to indicate a transformation between environmental representations. The letter "D" is used to indicate a derived environmental representation. These letters may be modified by a number to enumerate the various transformations, and by a prime (e.g., a ') to indicate a subset of the transformed representation.

The first type of transformation we need to consider is one that is invertable. That is one that can be transformed back to the base environmental representation without data loss or corruption. This is represented in the figure by the derived data set D1, and by the transformations T0 and its inverse.

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Now consider two more transformations. In the first, a subset of D1 (e.g., D1'), represented by the lightly shaded area of D1 is transformed into the derived environmental representation D2. The transformation performing this operation is labeled T6. One can also achieve the same effect by transforming directly from the base environmental representation. This is represented by the transformation labeled T2. Note that we are assuming that the transformation labeled T1 is not the inverse of T6. Once a transformation represented by either T2 or T6 has occurred the possibility of data loss and inconsistent environmental representations must be considered.

Next consider the transformations represented by T4 and T3. Since T4 transforms a subset of D2 (which is itself a subset of D1) the resulting representation must necessarily contain only a subset of the information in the base environmental representation. However representation D3 also contains information from an embedded environmental representation. Thus it can contain information that is different from and in conflict with the base environmental representation. Thus, while D3 and D3' may contain some overlap, they also contain unique information and they will in general not be consistent with each other.

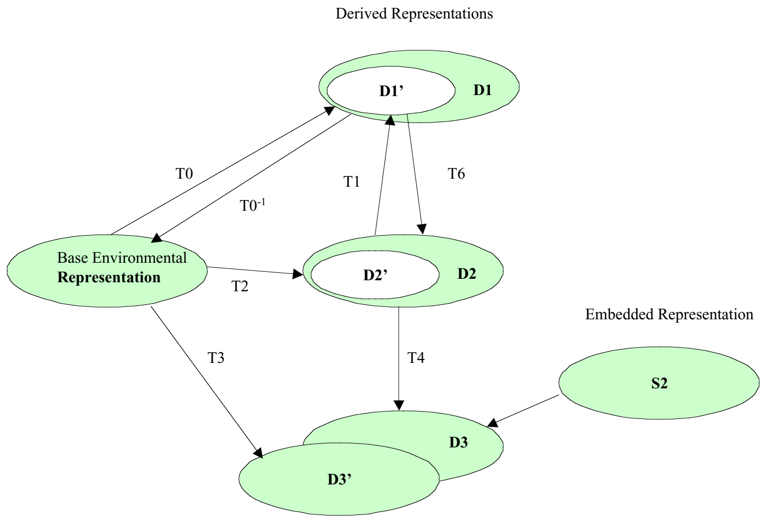

Figure 3. Notional Environmental Representation Transformations

3.1 The Consistency Process

The process required to achieve consistency across multi-level environmental representations requires, at a minimum, the following steps and rules:

3.1.1 Identify the base environmental representation (Rule 1)

The identification of a base environmental representation requires identification of all environmental models and parameters required by the federation and its federates. Much of this identification can be accomplished by examining the Simulation Object Models (SOM) from individual federates. However this *is* not sufficient. Parameters provided by embedded environmental representations must also be included and identified. This discovery process will require the use of both environmental and simulation subject matter experts. The investigations must be thorough and probing to succeed. As an example, if a simulation includes a RADAR model, but does not subscribe to RF propagation loss it most likely will have an embedded model. The model may be implicit, real, simple or sophisticated, but it must be present.

A complete list of all sensors used by any federate (or perhaps by the systems the federate abstracts) is required to accomplish an identification of the base environmental representation. If a federate represents a sensor in any way there is an implied requirement for an environmental representation to serve that sensor.

3.1.2 Identify the environmental representation of each federate (Rule 2)

Each federate has potentially different environmental representation requirements and potentially different signal injection points. The requirements of each federate must be identified. Once this is accomplished, the number and type of environmental representations required for the federation can be specified. Consistency of the multi-level environmental representation must be enforced in the selection process.

3.1.3 Identify all environmental parameters that can be simultaneously observed by two or more federates (Rule 3)

If a parameter cannot be observed by at least two federates at the same instant of time consistency is not measurable.

Observation can be either direct or indirect. There is relatively little latitude available for direct observations. For indirect observations the latitude is greater. For example consider two Radar's that observe the same contact in distinctly different RF bands. Each uses propagation loss and clutter models as part of their environmental representation. The propagation loss and clutter are never exchanged between the two Radar's, however the contact positions are. This would an example of an indirect observation of an environmental parameter.

Simultaneous observation includes both interpolated and extrapolated parametric values. One of the more important examples where extrapolation is used is dead reckoning. This situation can occur in any simulation, however it often occurs when a contact is handed off.

3.1.4 Determine the level of agreement required for common parameters (Rule 4)

Once a parameter has been identified as common between two federates the level of accuracy and resolution must be determined. This will in turn be determined by the measurement errors expected for each of the sensors. The environmental parameters used by each federate must agree to within the expected statistical error which the sensor(s) represented by the federate(s) expects to see. This requirement has important economic and programmatic implications. In some cases it will be necessary to mandate a single source for environmental representations. In others embedded representations may be acceptable.

The cost and effort required to disable embedded representation in legacy federates can be prohibitive. As a general rule, legacy federates will tend to include embedded environmental representations. Thus there will be strong incentives to retain the embedded environmental representations that must be balanced against the federation's goal and resources.

3.1.5 Identify (and probably disable) embedded environmental representations (Rule 5)

The determination of which embedded environmental representations can be retained will depend on the level of consistency required and the costs of disabling software in the target federate. The decisions at this stage of the environmental representation process will have significant impact on the fidelity and consistency of the entire federation. In general, the decision to accept embedded environmental representations where at least two sensors can simultaneously observe a parameter will place fundamental limits on the consistency a federation can achieve.

Signal injection points will generally be a significant consideration when determining which embedded environmental representation to retain. Signal injection points often assume different environmental representations than that implied by the native environment. That is federates may assume injection at some point in the environment or some point after the tactical sensor's interface with the environment.

3.1.6 Identify the content of each level of the environmental representation (Rule 6)

The content and algorithms used to define each level of environmental representation will depend strongly on the requirements of the federates. Each federate could potentially require its own environmental representation.

3.2 Develop and implement an environmental FOM

HLA rule [3] require that each parameter and interaction have a single owner. Ownership carries the privilege of updating and publishing. This implies several observations about parameters that are included in a federates Simulation Object Model (SOM).

First, attributes or interactions that represent the same thing at different levels of resolution may require distinct identities. Thus the positions of individual troops and aggregates derived from the individual positions are distinct under HLA. In some cases, such as when data is decimated, the same attribute might serve different levels of environmental representations. However this is not generally recommended.

The consistency across multi-level environmental representations must be built in during the FOM development process. This may require some difficult engineering decisions and probably will require some development. On the one hand, if federates are required to disable and use federate wide environmental representations they will be required to adapt. In any case, any attribute that cannot be derived using only the base environmental representation must be closely examined. This implies that a well-defined set of transforms exist between the base environmental representation and each parameter in the multi-level environmental representations.

This section has described six rules for determining consistency within a federation. In the next sections, the MARVEDS coalition and the application of the rules for consistency to the Integrated Ship Defense Federation are described.

4.0 MARVEDS

The Maritime Virtual Environment Data Specification (MARVEDS) initiative is a coalition of Naval programs. MARVEDS major thrust is to define a specification for the Naval synthetic natural environment. MARVEDS' approach is to build the specification by collaborating with Naval programs in synthetic natural environment use cases. The MARVEDS initiative began in early 1997. Today, MARVEDS works at two levels. Long term, MARVEDS is creating a Navy specification for environment representation, based on the needs of individual Navy programs. This is a top-down information engineering effort. Every year, MARVEDS representatives support individual programs such as the ISD M&S Pilot effort, working with the participants to create consistent environment representations in data and models. The results of yearly program support efforts provide input to the Navy specification, evolving the specification in direct response to user community needs.

The MARVEDS Working Group is a mediating organization, helping simulation builders use the environment data and models that are available in a coordinated way, matching existing environment data and models with users' needs. (The evolving MARVEDS specification is the documented expressions of user-provider understanding.) *S*upporting individual programs, MARVEDS representatives examine environment representations used by each constituent simulation model, examining data, calculations and assumptions, and recommending cost-effective approaches to creating consistent environment representations across the entire federation.

4.1 The MARVEDS Process

Consistent environment representations are created before the first simulation execution, so this is primarily where the MARVEDS team's support is directed. Regardless of whether the environment data and models are served centrally at runtime, distributed with simulation components, or even embedded within trusted legacy software, the time to create consistent environment representations is during simulation system development and integration.

A consistent environment is ensured by drawing from consistent, authoritative data sources, by using effects models with consistent assumptions and algorithm, and by examining systems models themselves to ensure they interpret the environment parameters in the same way.

Achieving consistent natural environment representations is a team effort, involving the roles of simulation system engineers, environment system engineers, simulation developers, and environment domain experts. Roles are emphasized, rather than individuals, because one individual may perform in more than one capacity.

The simulation system engineer has overall responsibility for delivering simulation capability on time, on schedule, and within budget. The MARVEDS process is designed to support the simulation system engineer by providing early input to allow choices in representation to fit the overall project schedule and budget. The environment system engineer ensures that the natural environment is considered as a single entity. Simulation developers (who understand the models) and environment domain experts (who understand weather, terrain, RF propagation and other phenomena) support the environment system engineer with specific insight and information where required.

MARVEDS provides environment system engineering and environment domain skills, with an information engineering process and product approach to achieve consistent environment representations cost-effectively.

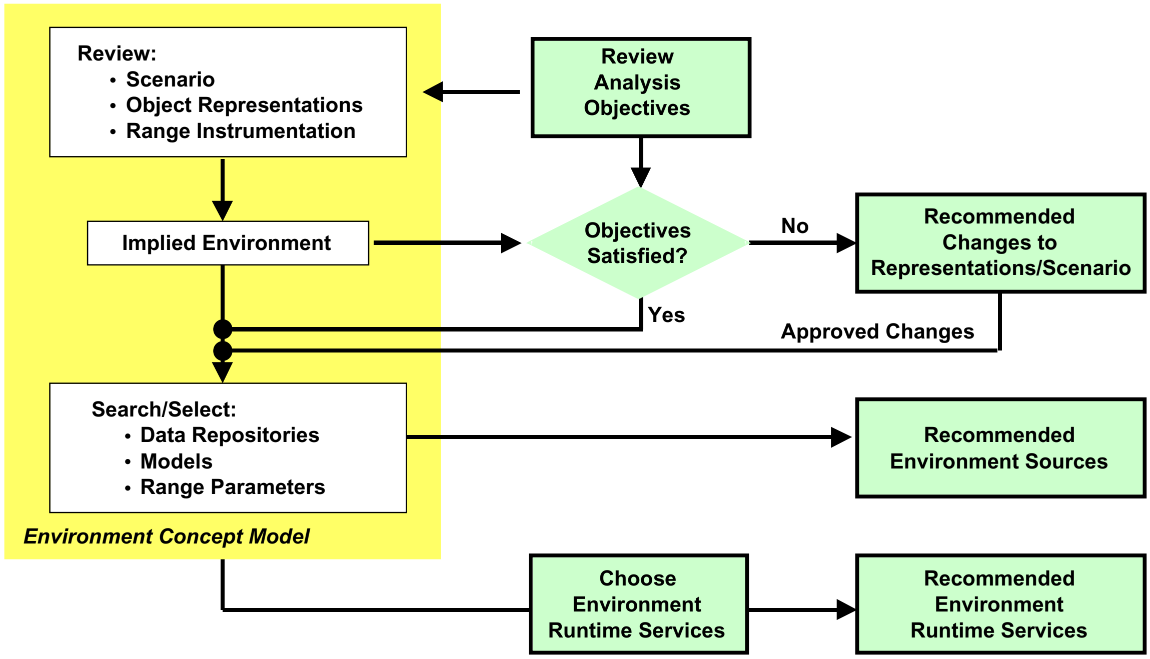

Figure 4. MARVEDS Consistent Representation Development Process

Figure 4 shows the MARVEDS process, developed specifically to support a program simulation system engineer in his effort to deliver responsive simulation capability on time and within budget. The process develops a recommended set of environment data, and models that constitute "just enough" consistent environment representation to produce valid simulation results.

The process begins by reviewing the underlying operational scenario, and the participants (both real and modeled) (rules 1&2). If the simulation will be used in support of test range activities, then range instrumentation is reviewed as well. Based on the this review one may develop early recommendations for changes to scenarios or military systems models, if there is no other cost-effective way to satisfy environment representation requirements, or if the system models contain embedded calculations (rule 5) which prevent consistent use of environment parameters. Here the MARVEDS team members work closely with the simulation developers to uncover explicit and implicit assumptions about employment of environment characterizations.

The process continues by selecting the set of environment data, models and, if applicable, range measurement parameters that constitute the needed environment representation, specific to the simulation requirements at hand (rules 3,4 &6). Here the MARVEDS team members are able to bring their knowledge of the available repositories and interchange specifications to the process.

The environment selection process is accompanied by a documentation capability that complements sound engineering judgement with standards-based software modeling languages and tools. This documentation capability is the environment concept model.

4.2 The Environment Concept Model

The environment concept model (the ECM) defines the purpose, structure and scope of environment representation for a simulation. It addresses data, algorithms and models. The ECM is the unified description of the environment representation across the federation, wherever that representation occurs. Thus the ECM is able to accommodate environment data and calculations which are embedded within the simulation.

Because the ECM contains an explicit description of the simulation requirements, it is application-specific. Thus, while one ECM addresses a limited battlespace, it addresses the specifics of that battlespace, including such potential "flashpoints" as implied environment characteristics, specialized systems, or unusual doctrine. However, because of the underlying physics similarities of electromagnetic sensors and communications systems, portions of environments documented in one ECM can be reused for subsequent ECMs.

The format of the ECM is a structured, machine readable file, which uses the syntax of the standards-based unified modeling language (UML). The principal leverage is that it enforces a consistent description of environment parameters and calculations throughout the model.

5.0 THE ISD USE CASE [4]

The ISD engineering pilot federation asked the MARVEDS team to participate in the development of the federation to insure a consistent synthetic natural environment was being implemented as part of the federation. The ISD federation is composed of the AN/SPS-49 Radar, Rolling Airframe Missile (RAM), the Close In Weapons System (CIWS) and the Ships Self Defense System (SSDS). Each federate is composed of a combination of both legacy and new models. The only federate to have a new synthetic environmental model was the AN/SPS-49.

The MARVEDS team following the procedures given in the previous section worked with the federate developers to determine if all were immersed in a consistent environment allowing a “fair fight” when the federation was in operation. In following the ECM we determined the ISD mission space, the environmental content of each federate, federate environmental data needs, what effects models were being used and what level of fidelity was needed by each participant. And finally we addressed how much environment was enough. As we proceeded through this exercise several observation stood out as critical to answering both the consistency and how much is enough questions. What we found was:
a) Having a clear understanding of the mission space within which the federates are operating sets the standard for determining the environmental consistency necessary for the federation. b) The existence of legacy and embedded code requires analysis to determine if the embedded environmental models within a particular federate are impacted by data from another federate or should be. c) Data that is consistent across the entire federation can be provided, however, each federate owning it’s own environmental model can result in the data being used significantly different between federates. d) It takes significant time and effort to determine if the model differences will have an impact on the results derived from the federation. and e) realizing the inconsistencies between models will be of value in determining the viability and utility of the federation. For the ISD federation we determined that the spatial, temporal and spectral domains within which the federation was required to interact were such that consistency across the entire domain could be achieved. Within the federation each federate required its own set of environmental parameters for use with its own models. Thus a consistent environmental representation could be achieved by constructing a common database for all federates to draw upon.

6.0 Follow-on Use Case

The ISD use case was the first use case for the MARVEDS coalition and demonstrated that a process (ECM) could be successfully employed for determining environmental consistency across an entire federation. This same process could be applied to any federation or federate. The ECM process could be applied to a training federation such as the BattleForce Tactical Trainer (BFTT). BFTT is a distinctly different configuration and purpose than the ISD. BFTT is a system composed of a control system providing scenario and other data to a set of On Board Trainers (OBT’s) connected to shipboard combat system sensors. Many of the OBT’s have their own embedded environment models. However, the process provided by the ECM does appear to be both extensible and portable allowing it to be applied in a straightforward manner to any federation or federate. BFTT will employ the MARVEDS team, using the ECM process, for defining a training meta FOM with the following benefits: building the synthetic environment representation once but used in many federations; discreet levels of resolution will be denied to assure consistent and repeatable aggregation and de-aggregation behavior; being able to rapidly assemble simulations in minutes vs. days or weeks; centrally manage configuration of the mission space representations; and eliminate duplication in mission space object development.

With a sufficient quantity of use cases the data captured by the ECM process will be used as reference and guidance in developing a synthetic natural environment specification for future meta-FOMS.

7.0 Conclusion

Consistency in representing the synthetic natural environment is critical for assembling meaningful distributed simulations. That consistency can be achieved today if the six rules presented are followed as part of the ECM process. Environment consistency in simulations could also be achieved if standardization of the mission space in terms of model resolution and fidelity were partitioned into discreet levels that could be coherently linked. The Naval training community is moving toward defining what those optimal levels of mission space representation should be, and hopes to present those levels for standardization as experience is gained in applying the ECM process across a number of use cases.

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REFERENCES

1. Birkel, P. A., *SNE Conceptual Reference Model,* In *Fall 1998 Simulation Interoperability Workshop, Workshop Proceedings and Presentations.* SISO paper 98F-SIW-018, September 1998.

2. Gross,D.C., *Report from the Fidelity Implementation Study Group,* In *Simulation Interoperability Workshop, Workshop Papers Spring 1999,* SISO paper 99S-SIW-167, March 1999.

3. High Level Architecture, HLA Technical Specification Rules, http://hla.dmso.mil/hla/tech/rules/

4. Chadbourne, C., Clark, D., Neel, T., *Insuring Consistent Synthetic Environmental Representation across an Engineering Federation- A First Use Case,* In *Fall 1998 Simulation Interoperability Workshop, Workshop Proceedings and Presentations,* SISO paper 98F-SIW-097, September 1998.