TOWARD A STANDARD SYSTEMS ENGINEERING PROCESS FOR DISTRIBUTED SIMULATION

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ABSTRACT

There are several different distributed simulation architectures in use today. Each of these architectures has an established user community with a recognized set of systems engineering practices and procedures for building distributed environments within their domain. Examples include the High Level Architecture (HLA) Federation Development and Execution Process (FEDEP) [IEEE 1516.3] and the Distributed Interactive Simulation (DIS) Exercise Management and Feedback Process [IEEE 1278.3].

Although existing process models generally work quite well within a given user community, the requirements imposed by modern, large-scale joint exercises and experiments often necessitate the integration of numerous dissimilar simulation assets. Since such assets are frequently owned by different user communities, it is necessary for developers within these communities to work together collaboratively toward common goals. However, the variations inherent in the local processes employed by these communities are recognized barriers to effective communication and thus increase risk from both technical and cost perspectives.

This paper describes a standards development project within the Simulation Interoperability Standards Organization (SISO) to develop a systems engineering process for all users of distributed simulation. The title of this product is the Distributed Simulation Engineering and Execution Process (DSEEP). SISO is developing DSEEP in its capacity as a standards sponsor for the Institute of Electrical and Electronics Engineers (IEEE). The DSEEP [IEEE P1730] does not specify a "one size fits all" process, but rather defines a generic systems engineering framework into which the lower-level practices native to each individual user community can be easily integrated. This paper will discuss the historical roots of the DSEEP, the current structure and content of the DSEEP document, and the SISO/IEEE standards development process being applied to guide the continued evolution of the DSEEP standard.

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INTRODUCTION

There are many activities that must be performed when building a distributed simulation environment. These activities range from early requirements development and domain modeling to the design, development, and execution of the simulation environment to the analysis and after-action review of simulation results. During project execution, it is vitally important that all stakeholders not only understand what these activities are, but also understand the overall process flow and the intermediate products that are produced when transitioning from one activity to another. It is this common view of the process that provides the foundation for project participants to fully understand their roles and responsibilities and how they need to interact with other project participants throughout the process to achieve the overall project goals.

The purpose of this paper is to describe a standards initiative within the Simulation Interoperability Standards Organization (SISO) that offers a common systems engineering process for all users of distributed simulation. The paper will begin with a general discussion of the origins of the Distributed Simulation Engineering and Execution Process (DSEEP), along with a short discussion of the cooperative standardization approach being followed underneath SISO and the Institute of Electrical and Electronics Engineers (IEEE). Then, a summary of the basic steps and activities inherent to the DSEEP will be provided. Finally, the paper will conclude with a description of the current status of this effort, along with a summary of next steps.

BACKGROUND

The origins of the DSEEP can be found in the High Level Architecture (HLA) Federation Development and Execution Process (FEDEP). The FEDEP began as a way to capture the lessons learned from the original HLA prototype federations during the period from 1995-1996. That is, as these applications shared their various strategies and approaches for constructing the federation, the FEDEP offered a summarization of these experiences in terms of a "best practices" guide for future HLA federation developers.

The first release of the FEDEP (in September 1996) was also influenced by the process model used in the Distributed Interactive Simulation (DIS) community. This process was entitled the "DIS Exercise Management and Feedback Process," and was already standardized as an IEEE Recommended Practice (IEEE 1278.3) [1]. Although the HLA had a broader scope than the real-time, platform-level class of users for which DIS was intended, the basic set of top-level steps identified in IEEE 1278.3 provided a template for defining a similar set of top-level steps in the FEDEP. Even at the more detailed "activity" level, the basic elements of the DIS process flow (e.g., requirements development, conceptual design, preliminary design, detailed design, construction and assembly; integration and testing) provided the foundation for the identification of corresponding activities in the FEDEP.

As the HLA began to achieve wider use, the HLA Architecture Management Group (AMG) became the forum for HLA users to share their development experiences and suggest possible enhancements to the FEDEP document. The AMG considered these change requests and approved those considered to be in the best interests of the HLA community. This process of continuous feedback resulted in a series of new FEDEP releases, with the last release (under direct DoD sponsorship) occurring in December 1999.

Shortly after the approval of the IEEE 1516 series of HLA specifications in 2000, a need was expressed within the HLA community for an

accompanying process model that would identify and describe the activities necessary to build federations compliant with either the new IEEE 1516 standard or the U.S. DoD HLA (v1.3) specifications. Using the FEDEP as the baseline to satisfy this need, the ensuing standards process allowed a much wider community of users to actively participate in the development of the process model. The IEEE Working Group consisted of 127 members, representing a wide range of interests both inside the U.S. and internationally, all actively participating in a series of comment rounds held over a two-year period (2001-2002). As a result of these efforts, the FEDEP was formally approved as an IEEE Recommended Practice (IEEE 1516.3) in March 2003 [2].

The Product Nomination (PN) for the first major revision of the IEEE 1516.3 standard was approved by the SISO Executive Committee (EXCOM) in February 2007. At the early meetings of the newly formed Product Development Group (PDG), the potential for expanding the scope of the document to include users of other simulation architectures was discussed. Specifically, mixed architecture applications were becoming much more common, and continually having to reconcile the different architecture-unique views of the development process was seen as a persistent barrier to effective collaboration across user communities. An overarching process model would allow these user communities to describe their native systems engineering practices in terms of a common framework, and thus facilitate the cross-community communication and teamwork that must take place for construction of such environments to even be possible.

The original partnership for this effort consisted of the HLA and DIS communities. However, representatives from the Test and Training Enabling Architecture (TENA) community also joined the PDG shortly after the scope of the effort was formally redefined. It was also at this time that a more architecture neutral title was given to the document to reflect the increase in scope (DSEEP).

At this time, the DSEEP document is actively evolving under the practices and procedures used by SISO/IEEE. The next section highlights the process used for standards development.

STANDARDS DEVELOPMENT

The SISO Standards Activity Committee (SAC) is the IEEE's standards sponsor for simulation interoperability standards. SISO is unique as an IEEE standards sponsor because it develops both IEEE standards and SISO-only standards, and also because it has both standards development and technical workshop activities under a single organization. The SISO-sponsored Simulation Interoperability Workshops (SIW) provide opportunities for attendees to participate in and see the direct results of their standards development efforts. Many standards efforts start as topics of significant interest at the workshops. In the case of the DSEEP, many of the modifications that are being considered in the current update were originally presented in workshop papers based on user experience with the standard.

For legal reasons, most standards development organizations (SDOs) such as SISO and IEEE have fairly similar processes to ensure openness, fairness, due process, and consensus (although consensus doesn't necessarily mean unanimous agreement). Most standards are drafted by a small group of dedicated technical experts but vetted with the broader community through a series of informal comment resolution cycles followed by formal balloting cycles. Figure 1 illustrates SISO's Balloted Product Development and Support Process [3]. For IEEE standards such as the DSEEP, IEEE's balloting and approval processes are used in lieu of SISO's process.

DSEEP DESCRIPTION

The DSEEP standard is intended to provide a recommended practice for users, developers, and managers who support the development and execution of distributed simulation environments. Specifically, DSEEP offers a comprehensive yet generalized process framework that can be easily integrated with lower-level systems engineering practices native to any distributed implementation strategy, such as DIS, HLA and TENA.

This process framework is identified by a sequence of seven basic steps that are commonly followed for developing and executing simulation applications within a distributed simulation environment. Figure 2 illustrates a detailed view of the DSEEP reflecting the flow of information across the seven process steps.

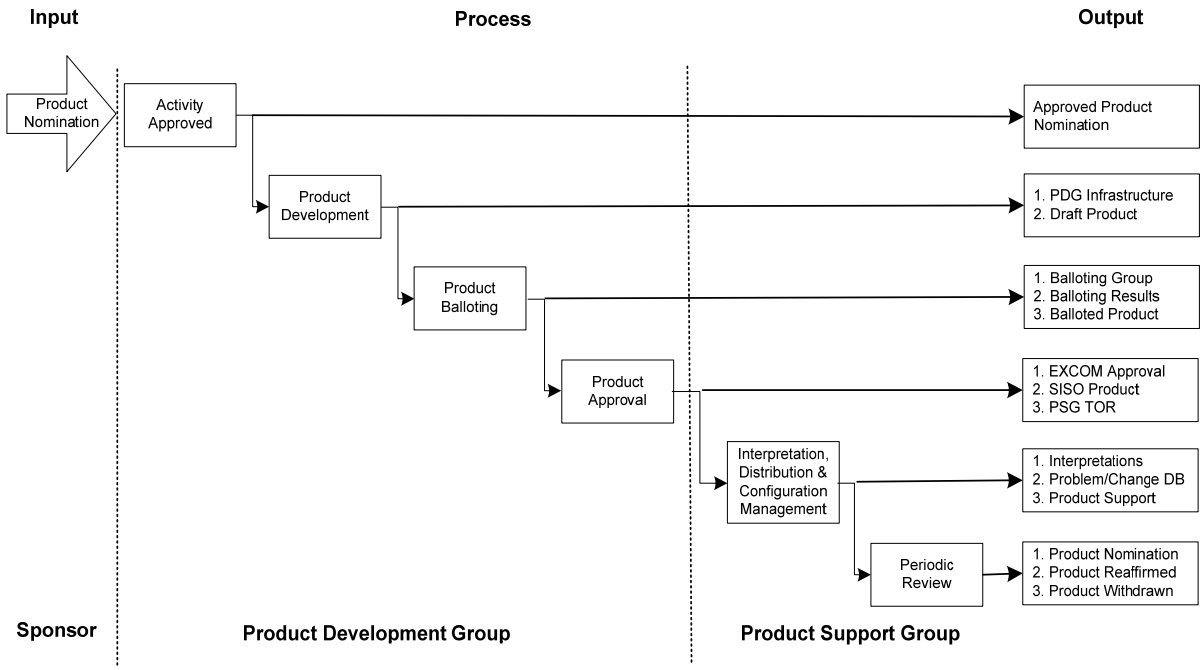

Figure 1. SISO Balloted Product Development and Support Process (BPDSP)

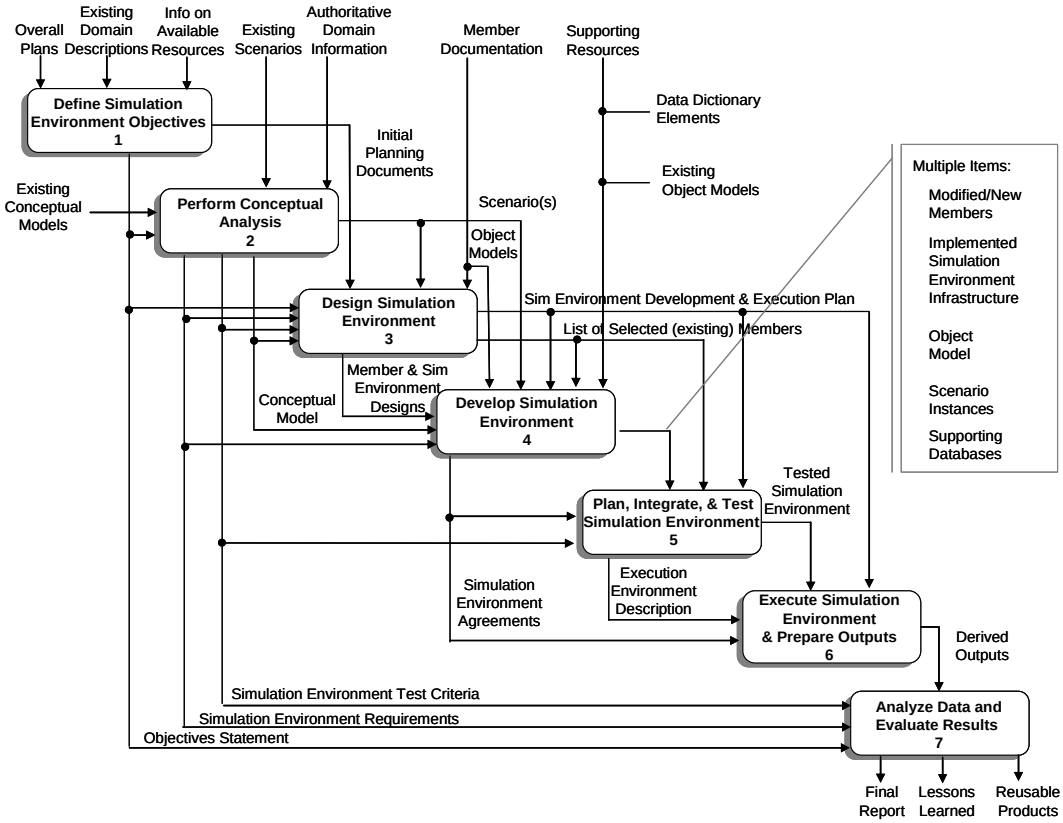

Figure 2. DSEEP Detailed View

These steps are further elaborated in Table 1.

Table 1 – DSEEP Steps

Step	Title	Description
1	Define Simulation Environment Objectives	The user, the sponsor, and the development team define and agree on a set of objectives and document what must be accomplished to achieve those objectives.
2	Perform Conceptual Analysis	Based on the characteristics of the problem space, an appropriate representation of the real world domain is developed.
3	Design Simulation Environment	Existing members that are suitable for reuse are identified, design activities for member modifications and/or new members are performed, required functionalities are allocated to the members, and a plan is developed for the development and implementation of the simulation environment.
4	Develop Simulation Environment	The information exchange data model is developed, simulation environment agreements are established, and new members and/or modifications to existing members are implemented.
5	Plan, Integrate, and Test Simulation Environment	All necessary integration activities are performed, and testing is conducted to ensure that interoperability requirements are being met.
6	Execute Simulation Environment and Prepare Outputs	The simulation environment is executed and the output data from the execution is pre-processed.
7	Analyze Data and Evaluate Results	The output data from the execution is analyzed and evaluated, and results are reported back to the user/sponsor.

Although many of the activities represented in the DSEEP diagram within Figure 2 appear highly sequential, the intention is not to suggest a strict waterfall approach to development and execution. Rather, this process illustration is simply intended to highlight the major activities that occur during development and execution and approximately when such activities are first initiated relative to other development activities. In fact, experience has shown that many of the activities shown in Figure 2 as sequential are actually cyclic and/or concurrent. Also, not shown are the feedback channels to previous steps that are supported and encouraged.

Table 2 identifies the types of products that are commonly developed and used for supporting the development and execution of a distributed simulation environment. Within this table matrix, "O" represents output items of a specific DSEEP Step, whereas "I" represents input items pertaining to a specific DSEEP Step.

Table 2 – DSEEP Products

	DSEEP Product	DSEEP Step						
		1	2	3	4	5	6	7
1	Objectives Statements	O	I	I				I
2	Initial Planning Documents	O		I				
3	Scenario Descriptions		O	I	I			
4	Conceptual Model		IO	I	I			
5	Simulation Environment Test Criteria		O	I		I		I
6	Simulation Environment Requirements		O	I	I			I
7	Simulation Exchange Data Models			O	IO	I		
8	Simulation Environment and Development and Execution Plan			O	I	I	I	
9	List of Selected Member Applications			IO	I			
10	Simulation Environment Agreements				O	I	I	
11	Modified/New Member Applications				O	I		
12	Implemented Simulation Environment Infrastructure				O	I		
13	Scenario Instances				O	I		
14	Supporting Databases				O	I		
15	Execution Environment Description					O	I	
16	Tested Simulation Environment					O	I	
17	Derived Outputs						O	I
18	Final Report							O
19	Lessons Learned							O
20	Reusable Products							O

The seven step DSEEP process can be implemented many different ways and with

specific outputs and inputs that may also be identified differently. The actual process flow and attention to detail and the specific product names truly depend upon the nature of the application and the unique requirements and constraints of a stakeholder's particular application area. For example, if it is a new project then each of these steps may be visited and products produced. However, if there is previous work that exists, then users can choose to reuse previous work, either in part or whole, along with the products of new developmental activities. And, again, this process also supports spiral development effort in which projects and products may be developed via multiple iterations and increments.

Let us briefly explore each of these DSEEP Steps further to understand the activities that take place, and the products that are developed and used.

Step 1 – Define Simulation Environment Objectives

The purpose of Step One of the DSEEP is to define and document a set of objectives that are to be addressed through the development and execution of a simulation environment. The inputs and outputs associated with this step are illustrated in Figure 3.

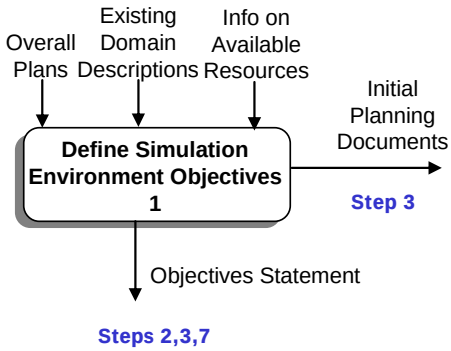

Figure 3. DSEEP Step 1 Thumbnail View

Within Step One, the following activities should occur:

- User/sponsor needs are identified (1.1)
- Objectives are developed (1.2)
- The initial planning is conducted (1.3)

The products that are produced during this step include (1) the Objectives Statements and (2) Initial Planning Documents.

Step 2 – Perform Conceptual Analysis

The purpose of Step Two is to develop an appropriate representation of the real world domain that applies to the defined problem space and to develop the appropriate scenario. It is here that the objectives for the simulation environment identified in Step One are transformed into a set of highly specific requirements that will be used during design, development, testing, execution, and evaluation. The inputs and outputs associated with this step are illustrated in Figure 4.

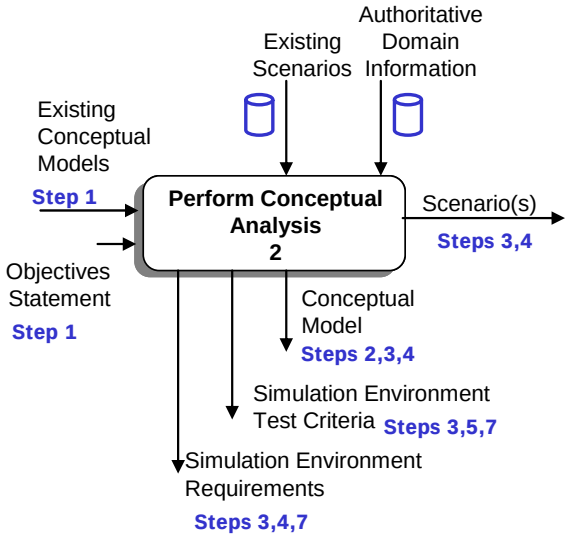

Figure 4. DSEEP Step 2 Thumbnail View

Within Step Two, the following activities should occur:

- The scenario is developed (2.1)
- The conceptual model is developed (2.2)
- The simulation environment requirements are developed (2.3)

The products that are produced during this step include (1) scenario descriptions, (2) the conceptual model, (3) simulation environment test criteria, and (4) simulation environment requirements.

Step 3 – Design Simulation Environment

The purpose of Step Three is to produce the design of the simulation environment, which will be implemented in Step Four. This involves identifying applications that will assume some defined role in the simulation environment (members) that are suitable for reuse, creating new members if required, allocating the required functionality to the members, and developing a

detailed plan for the development and implementation of the simulation environment. The inputs and outputs associated with this step are illustrated in Figure 5.

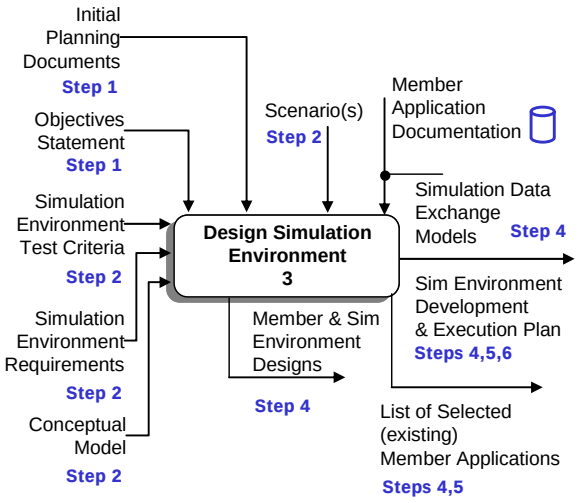

Figure 5. DSEEP Step 3 Thumbnail View

Within Step Three, the following activities should occur:

- Member applications are selected (3.1)
- The simulation environment design is prepared (3.2)
- The detailed plan is prepared (3.3)

The products that are produced during this step include (1) the simulation data exchange models, (2) a simulation environment and development and execution plan, and (3) a list of selected member applications.

Step 4 – Develop Simulation Environment

The purpose of Step Four is to define the information that will be exchanged at runtime during the execution of the simulation environment, modify member applications if necessary, and prepare the simulation environment for integration and test (database development, security procedure implementation, etc.). The inputs and outputs associated with this step are illustrated in Figure 6.

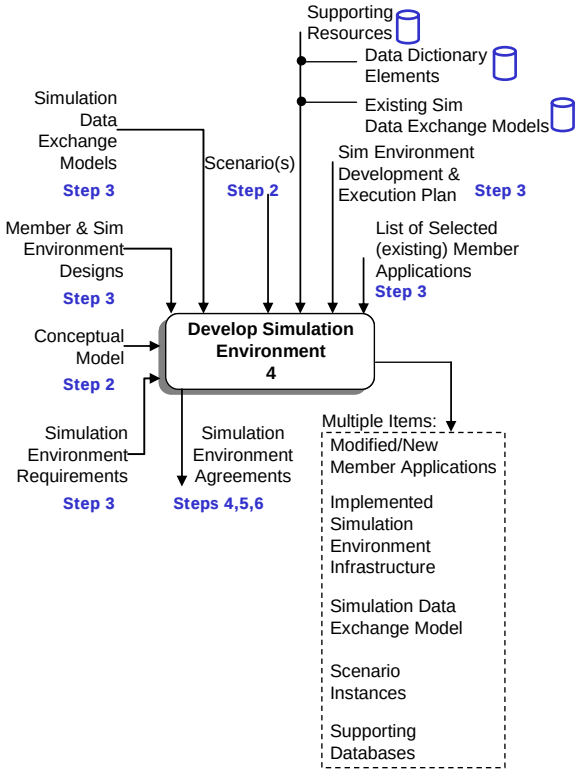

Figure 6. DSEEP Step 4 Thumbnail View

Within Step Four, the following activities should occur:

- Object models are developed (4.1)
- Simulation environment agreements are established (4.2)
- Member application designs are implemented (4.3)
- The simulation environment infrastructure is implemented (4.4)

The products that are produced during this step include (1) simulation environment agreements, (2) member applications, which are modified or new, (3) an implemented simulation environment infrastructure, (4) an update to the simulation data exchange model, (5) scenario instances, and (6) supporting databases.

Step 5 – Plan, Integrate & Test Simulation Environment

The purpose of Step Five is to plan the execution of the simulation environment, establish all required interconnectivity between member applications, and test the simulation environment prior to execution. The inputs and outputs associated with this step are illustrated in Figure 7.

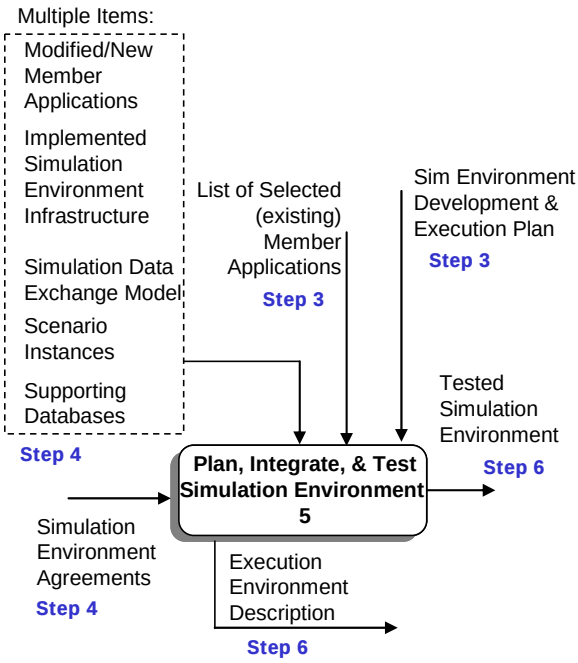

Figure 7. DSEEP Step 5 Thumbnail View

Within Step Five, the following activities should occur:

- The simulation environment development and execution plan is executed (5.1)
- The simulation environment is integrated (5.2)
- The simulation Environment is tested (5.3)

The products that are produced during this step include (1) an execution environment description, and (2) a tested simulation environment.

Step 6 – Execute Simulation Environment & Prepare Outputs

The purpose of Step Six is to execute the simulation environment and to pre-process the resulting output data. Figure 8 illustrates the key activities in this step of the DSEEP. The inputs and outputs associated with this step are illustrated in Figure 8.

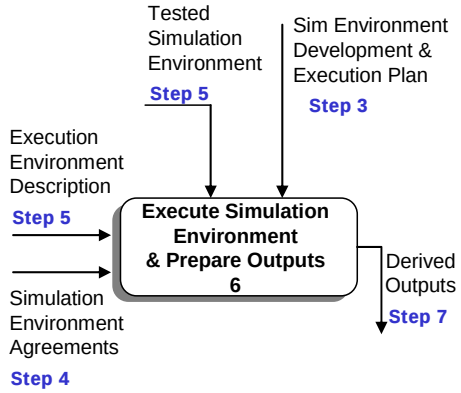

Figure 8. DSEEP Step 6 Thumbnail View

Within Step Six, the following activities should occur:

- The simulation environment is executed (6.1)
- The simulation environment outputs are prepared (6.2)

The key product that is produced during this step is a set of derived outputs resulting from the execution.

Step 7 – Analyze Data and Evaluate Results

The purpose of Step Seven is to analyze and evaluate the data acquired during the execution of the M&S environment (Step Six) and to report the results back to the user/sponsor. This evaluation is necessary to ensure that the M&S environment fully satisfies the requirements of the user/sponsor. The results are fed back to the user/sponsor so that they can decide if the original objectives have been met or if further work is required. In the latter case, it will be necessary to repeat some of the DSEEP steps again with modifications to the appropriate products. The inputs and outputs associated with this step are illustrated in Figure 9.

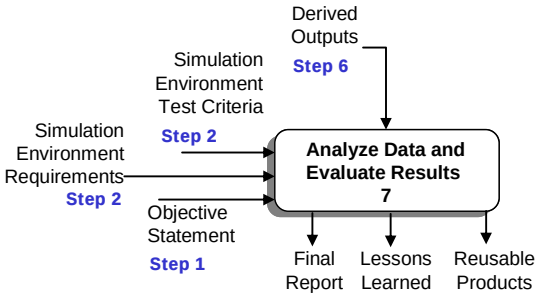

Figure 9. DSEEP Step 7 Thumbnail View

Within Step Seven, the following activities should occur:

- The execution data is analyzed (7.1)
- The results are evaluate and feedback to participants (7.2)

The products that are produced during this step include (1) a final report, (2) lessons learned, and (3) a set of reusable products.

DSEEP ANNEXES

Because the body of the DSEEP has been broadened from the original FEDEP, valuable details unique to HLA federation development have been removed from the body of the standard. Analogously, the DIS-specific detail currently found in IEEE 1278.3 is also absent in the body of the DSEEP document. The intention was not to ignore this valuable detail, but to consolidate it in annexes to the body of the standard that provide the protocol-specific mappings.

Thus far, both the HLA and DIS mappings have been incorporated into the evolving standard, and a TENA mapping is expected in the near future. Other mappings may be introduced in subsequent DSEEP revisions. Each overlay has the same structure as outlined in Table 3. The annexes provide the detailed information users need to apply the standard without referring to another document. By referencing the appropriate annex for the protocol they're using, they will have protocol-specific guidance for developing their simulation environment.

Table 3 – DSEEP Annex Structure

Section 1: Terminology Mappings and Definitions	This section provides mappings between the generic terminology used in the DSEEP and the domain-specific terminology used in the architecture. • Terminology mappings (e.g. simulation environment to federation) • Definitions (e.g. federation, federate, federation object model)
Section 2: Global Mapping (Specific Architecture/Methodology to DSEEP)	This section provides general guidance on how to map the architecture-specific process to the DSEEP. • Because the DSEEP is based on IEEE 1516.3 (FEDEP), this is a trivial one-to-one mapping for HLA. • For DIS, a mapping of the five-step IEEE 1278.3 Exercise Management and Feedback Process to seven-step DSEEP is provided.
Section 3: Detail Mappings (Specific Architecture/Methodology to DSEEP)	This section provides the detailed, step-by-step mappings from architecture-specific process to the DSEEP (a refinement of Section 2). • For both DIS and HLA, this section is the primary location for defining lower-level activities unique to those architectures. Examples include such HLA-specific activities as the development of time management strategies and development of the FOM.
Section 4: References (Annex-specific)	This section provides references to protocol-specific documents such as the protocols themselves and predecessor process standards.

Note that in the multi-protocol environments that are becoming increasingly common, it's straightforward to create a many-to-many mapping between several protocols to determine what should be done in each protocol environment at each step, perhaps in the form of a spreadsheet that would allow simulation environment developers to verify that simulation environment engineering is proceeding synchronously for each protocol.

CURRENT STATUS/NEXT STEPS

The schedule for the DSEEP standardization effort is shown in Figure 10.

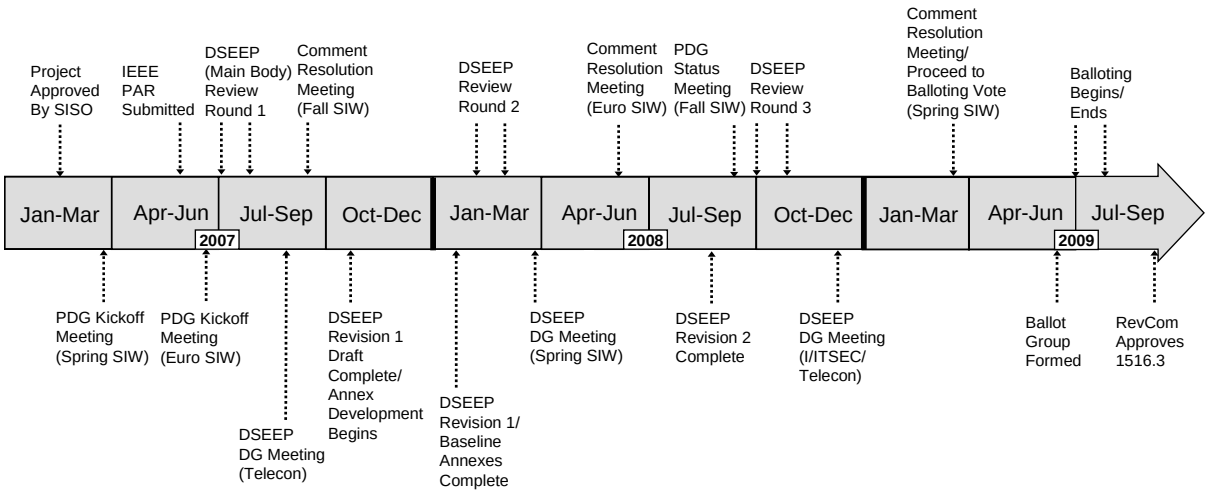

Figure 10. DSEEP Development Schedule

Presently, the second comment round for the DSEEP document has been completed, and comment resolution is in progress. A third comment round will begin in fall 2008, with IEEE balloting anticipated for summer 2009. Resolution of comments received via the balloting process will take place immediately thereafter. The final approval of the new DSEEP standard (IEEE 1730) is projected to occur sometime in late 2009.

SUMMARY

This paper has provided an overview of the DSEEP, a common process model for distributed simulation development. Through proper application of the DSEEP, developers can collaborate much more effectively throughout the end-to-end development process. The DSEEP is flexible in that it provides the means for participants to map their native domain-specific practices and methodologies to a single common higher-level process and thus provides a framework for effective communication.

Interested parties are invited to join the DSEEP PDG. Membership in the PDG can be achieved by simply going to the SISO website (www.sisostds.org) and subscribing to the DSEEP reflector. To participate in DSEEP balloting in 2009, one must join the IEEE Standards Association (SA). Instructions for joining the IEEE-SA can be found at www.ieee.org.

REFERENCES

[1] IEEE 1278.3-1996, "Recommended Practice for Distributed Interactive Simulation - Exercise Management and Feedback", 10 December 1996.

[2] IEEE 1516.3-2003, "Recommended Practice for High Level Architecture Federation Development and Execution Process", 23 April 2003.

[3] Simulation Interoperability Standards Organization, "Balloted Products Development and Support Process," SISO-ADM-003-2008, 8 January 2008.