THE SYNTHETIC ENVIRONMENT DATA REPRESENTATION AND INTERCHANGE SPECIFICATION (SEDRIS) DEVELOPMENT PROJECT

Paul G. Foley, MITRE Corporation
Defense Modeling and Simulation Office
1901 North Beauregard Street, Suite 504
Alexandria, Virginia USA 22311
703-998-0660, FAX 703-998-0667
pfoley@msis.dmso.mil

Farid Mamaghani, Independent Consultant, Institute for Defense Analyses
19223 SE 45th Court
Issaquah, Washington USA 98027
425-641-6192, FAX 425-641-6192
farid@halcyon.com

Dr. Paul A. Birkel, MITRE Corporation
1820 Dolley Madison Boulevard
McLean, Virginia USA 22102-3418
703-883-6399. FAX 703-883-6435
pbirkel@mitre.org

ABSTRACT

A common representation of the physical environment is a critical element in Modeling and Simulation (M&S) and is a necessary precondition for the interoperability of heterogeneous simulations. The level of interoperability achieved depends heavily upon the degree of consistency, completeness, and unambiguous definition of environmental data. Today, no uniform and effective standard mechanism exists for describing, reusing, and interchanging environmental data among M&S applications. Additionally, data sharing rarely occurs between the operational and simulation communities even though each community uses representations of the same physical aspects of the real world. The SEDRIS project was conceived and implemented to capture and provide a complete (terrain, ocean, atmosphere, and space) data model of the physical environment, access methods to that data model, and an associated interchange format. These SEDRIS developed mechanisms facilitate interoperability among heterogeneous simulations by providing complete and unambiguous interchange of environmental data. The range of M&S applications addressed in the SEDRIS development includes training, analysis, and system acquisition and supports visual, computer generated forces, and sensor perspectives. When completed in 1998, the data interchange specification will support the pre-runtime distribution of source data, three-dimensional models, and integrated databases that describe the physical environment for both simulation and operational use.

INTRODUCTION

The generation of databases that represent the physical world is a key component in establishing a modeling and simulation (M&S) capability to support training, analysis, and acquisition applications. Database generation systems are faced with the challenge of establishing consistent and correlated databases for M&S system use at the lowest possible cost in time and cost. This paper addresses the development of an efficient and effective interchange mechanism that allows database generation systems to receive source materials through a common interface, and also supports the interchange of the integrated databases produced by those systems.

BACKGROUND

For many years the U.S. Department of Defense (DoD) has been working to achieve the ability, through M&S, to analyze military system capability and force-structure requirements. Simulation applications that meet these needs must be able to develop, test, and evaluate required system performance; and train Military Service members, from individual combatants to Joint Task Force Commanders.

In the early 1980s, the DoD initiated a development program to address database generation cost and production timeline coordination issues associated with supporting various visual scene generation systems. This combined Air Force, Army, Marine Corps, and Navy program, Project 2851, resulted in the definition of the Standard Simulator Database Interchange Format (SIF) and the creation of the Standard Simulator Database Facility (SDBF), currently located at Kirtland Air Force Base, Arizona. The intent of the program was to allow reuse of previously generated databases, reduce the amount of data transformation required to support various existing simulator database designs, and provide better response to user community requirements.

Until the mid-1980s, the DoD deployed simulation systems and simulators in stand-alone modes. These M&S applications were developed to primarily support procedural and proficiency training, and operational mission rehearsal. In 1986, the Defense Advanced Research Projects Agency (DARPA) Simulation Networking (SIMNET) Program introduced the concept of networking homogeneous, and subsequently heterogeneous, simulators. Between 1991 and 1993 the culmination of SIMNET and follow-on developments, coupled with the requirement for a common environmental representation to ensure a “fair fight”, highlighted the design deficiencies of SIF when used by networked simulation systems. The most notable deficiencies were the lack of a comprehensive data model and data dictionary, software access libraries, and a focus on data interchange consumers in stand-alone (non-networked) visual systems and sensor simulation domains.

The U.S. Army Close Combat Tactical Trainer (CCTT) development, begun in the early 1990s, further highlighted these deficiencies by identifying several classes of data representation extensions required to meet mission needs. Since Project 2851 was not required to meet the needs of networked simulation and new requirements have evolved since its design, it idoes not meet the needs of computer-generated force (CGF) simulations, and is not well suited for high-density terrain databases. It also was not designed to support ocean, atmosphere, space, and some terrain objects described in current joint and/or networked system requirement documents. Furthermore, attempts to modify and improve SIF have been program specific, marginally successful, and generally not extendable.

Therefore, without an effective interchange mechanism, most simulated environment database interchange continues to be accomplished by point-to-point unique conversions between two applications, as shown in Figure 1, for six networked simulations.

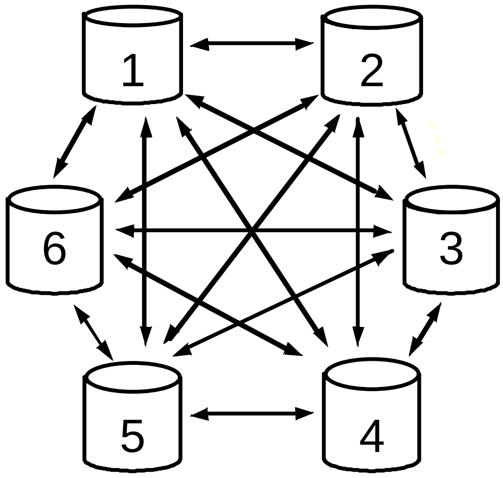

Figure 1. Point-to-point interchange (each arrowhead is a unique conversion software module)

Conversion of one system’s data to another format is based upon rigidly defined database format specifications for both the source and target M&S system. Because of the differing proprietary database formats, each conversion requires the development of a customized data converter software application. These point-to-point solutions are expensive, time consuming, and often unreliable. To meet the specific implementation needs of the target system, the converted database usually undergoes several additional conversions before a useable run-time format is obtained. Each conversion adds to the risk of data loss or corruption. Additionally, the number of unique conversions increases geometrically with the number of sources involved. Development and maintenance of these conversion software modules is cost-prohibitive. Based on these factors, a new solution to support the efficient interchange of simulated environment databases was required. The SEDRIS Project was initiated to address these issues.

SEDRIS PROJECT OBJECTIVES

The U.S. Defense Modeling and Simulation Office (DMSO) sponsors the SEDRIS Project. The DMSO-authored DoD Modeling and Simulation Master Plan (MSMP), DoD 5000.59-P, states that providing timely and authoritative representations of the environment is a core requirement in order to achieve interoperability among aggregated heterogeneous simulation systems. Toward meeting this need, the SEDRIS Project was given the general objective of solving the M&S system environmental data interchange problem. However, in accomplishing that objective, the SEDRIS Project also solves the related interchange and reuse problems encountered by database producers and operational users.

In the context of promoting environmental data reuse and interoperability, the specific objectives of the SEDRIS development effort are to:

- Capture the complete set of environmental data elements and their relationships in the context of a data model
- Provide a software library implementing a standard application programmer's interface (API) for access to data elements
- Minimize cost to access and reuse environmental data by lowering the software barrier to entry
- Provide a standard data interchange mechanism between database builders and consumers
- Facilitate interoperability of networked heterogeneous simulations
- Support reuse of environmental databases between disparate simulations
- Use the same data model for both completed database interchange and as an access mechanism to import and export source data into and out of various database generation systems.
- Promote a consensus understanding of the diverse requirements and implementation choices used within the broad M&S community through education

WHAT CONSTITUTES A SIMULATED ENVIRONMENT

A simulated environment database, for use in M&S applications, is an integrated set of data elements that describes a defined geographic region. It must contain a consistent and correlated description of the environment (terrain, ocean, atmosphere, and space) that is appropriate to the simulation objective. Additionally, it often includes data describing simulation elements and events expected to take place during simulation execution. For example, data representing trees in a forested region may be found in the database along with data describing the geometry of the vehicles that may drive through the forest and impact trees during a training exercise.

There are several general classes of data that pertain to simulated environment databases and the database generation process: surface and volumetric data, 2-D and 3-D feature data, 3-D models and icons; texture, image and color data; material attributes; and various animations that describe predetermined effects.

Surface and volumetric data can be derived from both regular or irregularly spaced gridded fields based on measured or remotely sensed observations. Examples include digital elevation models, digital bathymetry, and complex grids that describe various properties of the ocean, atmosphere, and space. From these source matrices and 3-D grids, supplemented by value added updates, various simulation database generation systems derive the terrain skin, ocean and river bottom, ocean and river surface, cloud and pressure surfaces in the atmosphere, thermal boundaries in the water column, and various space effects. To create earth surfaces, these source data are further processed into regular or irregular networks of typically triangular shaped polygons.

Feature data represent both manmade and natural objects. Examples include weather fronts, forests, agricultural fields, water bodies, roads and river networks, volumes of atmosphere, ocean or space, and individual objects such as trees and buildings. Some objects may have moving parts (e.g., trees, drawbridges, windmills, and industrial cranes). Usually these data represent separate source input to the database generation process and therefore must be correlated with the applicable surface (e.g., ensure rivers flow downhill, roads are driveable, small water body and rice paddy surfaces are at constant elevation). In terrain representation, if feature ground elevations are provided, they are the preferred source for generating the terrain skin in dense feature areas. It is becoming common practice to integrate feature ground elevation data (either provided from direct observation or interpolated from elevation matrices) prior to generating the terrain skin and thus reduce the editing required to ensure correlation.

3-D models and icons are also used in simulation. These data reflect detailed 3-D surface geometry often derived from Computer-Aided Design (CAD) files, as-built blueprints, or from various image extraction techniques. In this manner, high-resolution data that describe stationary and movable systems, equipment, and structures can be entered into the simulated environment database.

When visualizing surface and feature data, color and texture are important in conveying added information. The color and texture data are either extracted from image sources or derived from geographic area or engineering inference techniques.

Rendering data in the non-visual spectrum also requires attributes such as acoustic characteristics, surface materials, or electromagnetic properties. These data include sensor signal reflectance, absorption and transmission attribution on surface materials and volumes, and trafficability data that affect sensor system performance and human or vehicle dynamics during simulation execution.

The resulting data are then integrated with surface data to generate the desired appearance (e.g., field and water surface patterns, road and building surfaces, sound reflections, electromagnetic signature, and clouds). Other attribution must also be carried in the simulated environment database to support computational tasks required by the simulation.

A simulated environment database may also contain data describing predetermined events that are captured in the form of short animations. These could include explosion effects, surface drainage patterns, or state changes for specified objects. Other data are included to convey connectivity (topological relationships), system specific data necessary for computations (e.g., precomputed visibility, occulting planes) and to produce electronic or paper maps and charts (e.g., names and labels).

All of these required data and information components must be addressed by a robust interchange specification designed to support both source data input to the database generation system and reuse of its integrated database output products.

INTERCHANGE CHARACTERISTICS

There is only one ground truth. Therefore, there is a single physical environment that all simulation applications are striving to represent. That physical environment is large and diverse, requiring the efforts of many producers to gather, analyze, define, and describe data elements as part of the database generation process. Users of these simulated environment databases have system-unique, often widely diverse, requirements for fidelity, maintainability, and run-time representation. Consequently, each application organizes its representation of the ground truth data to suit specified simulation objectives.

Establishing simulation networks, or federations, ties the participating applications to a common scenario. If these separate applications are to join in a common scenario, they must share a common ground truth that implies a two-way interchange of information and perception. But what initially appears as a simple swapping of databases is in reality much more complex. To use the data, all applications must speak the same language and derive the same information from the interchange. It is that common interpretation, or perception, of the environmental data through use of a common language and unambiguous description that defines successful interchange.

From the viewpoint of the M&S application, there are three factors that affect representation of the various data types that comprise a simulated environment database:

- Representational Polymorphism: Applications, despite sharing a common geographic area requirement, often only need a subset of an entire data set developed for a larger simulation network or federation. This means that these applications find the remaining data irrelevant to their needs and would prefer not to be burdened by those representations during data processing following receipt of a transmittal.

- Representational Completeness: The method by which the same data type is viewed can be radically different across applications. The type itself is not the issue, but the form in which it is expected becomes important (e.g., as a 3-D CAD model, a 2-D building, or a 1-D symbol) and if not found can lead to serious divergence among the resulting application-specific simulated environment databases.

- Representational Efficiency: The format of a representation is often just as critical as the capabilities of the methods used for its access and the efficiency of those methods. While the individual data elements of the representation may be complete, they may not be concise or their relationships may not be explicitly maintained.

The combination of these three factors results in a potential multiplicity of data representations and implementations, all of which are important to some consuming application. The problem is that information (data elements, relationships, encoding) viewed by one user could be interpreted as noise by another.

Therefore, interchange comprises both consensual sharing of data and acceptance of a common definition of the interchanged information. An agreement must be reached to convert from one format to another or adopt a common transmittal specification that can serve as the basis for the interchange. Consensual sharing has been tried in a variety of ways and has never achieved wide success with its win-lose characteristic. To implement a common definition, an effort must be made to capture all practical data types and their relationships, and to generate a robust and efficient data model and database interchange mechanism that meets the needs of a broad-based user community.

Additionally, when the shared simulated environment has to be accessed by a wide range of applications, each expecting to see the data elements in an application-specific context, it makes efficiency and elegance in data interchange difficult to achieve. Fortunately, there is a bound to both the types of data elements and the accepted methods by which applications represent and access those data element types. This makes the interchange challenge more manageable in describing a data model and accessing its data through software, but it does not simplify it.

The key characteristics of an interchange specification that meets the environmental data representation needs of the M&S community are:

- The unambiguous description of the complete environment: The representation must capture the full spectrum of environmental data used in today's simulation applications and be easily extensible to incorporate future needs. It must not make any assumptions about data resolution, and must support the data types required in a variety of disparate systems, while capturing their relationships to one another. The data format that instantiates the conceptual data model must also embody these characteristics in an efficient form.

- A standard interface for data access: Access to data must be based on a common standard software interface that provides a simple, efficient, and intuitive method for interacting with data in a transmittal. The application programmer's interface (API) must be coherent, complete, and preclude the replication of data and media access libraries which are currently common across all applications and platforms. The API must make the underlying format transparent (but not inaccessible) to users by clearly conveying the view of the data model without regard to the specific media format.

Additionally, common reusable supporting applications and tools, based on the API, must be available to developers to assist them in producing their application-specific software that can access and utilize transmitted data. These tools and applications must include common conversion utilities, transmittal verification tools, helper applications, and data viewing and examining applications.

IMPORTANCE OF THE DATA MODEL

A data representation model is a description of the data elements, including their attributes, and the logical relationships between those data types. In object-oriented terminology, this is viewed as a class-hierarchy. Each major data type with important or explicit relationships is captured to show its logical relationship to other data types. The strength of the data model is its capability to define these data relationships completely and unambiguously.

It is often easier to communicate with a data model serving as a meta-model of the data, than with the actual data. This is so because the meta-model describes the data through their attributes rather than through their storage formats. The data model removes ambiguity by ensuring that all types of environmental data are captured and relationships between alternate representations (e.g., feature versus geometry) are defined. Using a polymorphic approach, multiple representational views can be supported, e.g.:

- A 3-D view which incorporates all forms of visual and non-visual sensors (including communications)
- A 2-D overhead view for maps and charts
- A computational (or reasoning) view for use by CGF algorithms

A data model supports development of an API for use in accessing the data. It therefore enables the reuse and interchange of simulated environment data since data producers and users can readily develop software tools, utilizing the API to convert their native data representation to and from the data model.

SEDRIS DATA MODEL DESIGN

Data model development was the initial effort towards achieving a method for data interchange in the SEDRIS Project for a number of reasons. Of primary concern was the design and evaluation of an interchange specification capable of meeting all M&S application needs. Only by developing a data model, with supporting standard API and native database conversion software, could this capability be fully tested. This approach provided the development team the tools to ensure that all data were supported, and relationships between data elements were properly maintained. Changes to the data model are accompanied by updates to the API and conversion software as needed.

Initially, a core team of individuals with extensive experience in developing simulation databases was assembled to draft a data model in support of all environmental data needed by simulations. The core team adopted a modified Rumbaugh notation as the means to establish a true object model design. Industry review was then solicited in order to gather insight through use of the data model.

Industry participants were selected from responses to a Broad Agency Announcement (BAA) process. The industry participants were directed to use and evaluate the data model. A broad spectrum of data providers, database developers, and applications developers was selected to ensure the data model was complete and capable enough to support a wide variety of environmental representations and vendor unique database designs. An associate developer relationship was implemented to achieve maximum leverage of contractor experience, thoughts, and approaches, in recommending changes to the data model.

All associate contractors were tasked to develop a document which maps their data, or an established data format (e.g., the Vector Relational Format part in NATO STANAG 7074) to the data model. This process was used to ensure that there were classes and sufficient organization in the data model to support the types of data required and the relationships between those data elements. The contractors also mapped from the data model to their proprietary or assigned native data format. This two-way mapping and assessment, accompanied by specific improvements and suggestions, was submitted for incorporation into the data model design.

FEATURE AND ATTRIBUTE CODING CATALOG (FACC)

The FACC is the international standard for coding and attribution within the Digital Geographic Information Exchange Standard (DIGEST). DIGEST is NATO STANAG 7074 and the U.S. National Imagery and Mapping Agency (NIMA) specifies use of the FACC in generating all vector products. The SEDRIS data model references the FACC enumeration.

As part of the SEDRIS Project, enumeration is being defined for all terrain, atmospheric, oceanographic, and space data elements and attributes required by M&S applications. This will require extensions to the FACC that will be proposed through established approval processes managed by NIMA.

INTERCHANGE SPECIFICATION DEVELOPMENT

The SEDRIS Project approach to interchange standardization involves the development of standard read and write APIs, conversion software, a data interchange format, and a transmittal validation process that support a standard data model design. This approach does not solely focus on specifying an interchange format, but also provides for the generation of APIs and conversion software to support application formats currently in use by the M&S community. The APIs provide a standard and reusable method for interfacing with the data model. Conversion software developed by the SEDRIS associate contractors using both the data model and data interchange format in combination with the standard APIs has been used to interchange their databases. The transmittal validation process ensures the robustness of the data model, APIs, and contractor conversion software. Deliverables from the SEDRIS development are:

- A common semantics and syntax described in an enhanced Rumbaugh object model with associated data dictionary and embedded metadata rules with sample templates to facilitate implementation.
- A data interchange mechanism specifying the interchange format, rules for generating compliant transmittals, and interface descriptions to data model representations.
- A standard application programmer's interface (API) and associated tools and utilities to view and check transmittal content.

Associate contractors' primary focus is to ensure the completeness of the data model and provide themselves and the community with tools that facilitate use of SEDRIS deliverables. The design objectives for the SEDRIS deliverables are:

- The data model and interchange format use must not hinder interoperability
- The original data should be preserved to the greatest extent possible
- Data derivation (if any) must be under the control of the application, not hidden in the API
- Data model deficiencies leading to data loss, must not occur
- Standard definitions should be used for data elements to the maximum extent possible
- The data model must support standard data formats, especially those used by primary data providers. Defense, Federal, and International products and formats include: the standard digital products specified by the National Imagery and Mapping Agency (NIMA), the Gridded Binary (GRIB) and Binary Universal Format Representation for Meteorological Data (BUFR) formats of the World Meteorological Organization (WMO), and formats used in the U.S. Navy administered Oceanographic and Atmospheric Master Library and specified by the U.S. Air Force Weather Agency. Industry sources include the database formats used by the major computer image generation system companies and model developers and geographic information system vendors.
- The interchange mechanism should strike a balance between practicality and elegance
- The implementation should be kept separate from the capture of critical data model concepts
- The interchange specification must not impose unreasonable resource demands, and be efficient in handling data

DATA INTERCHANGE FORMAT

The data interchange format has been evaluated through a series of interchange experiments among the SEDRIS associate contractors. These interchange experiments used an interim format design and implementation to test the robustness of contractor conversion software, and allow efficiency considerations to be explored in developing the final data interchange format.

Format design considerations include optimization for search, efficient accessibility of data, and final transmittal size. An API has been developed in order to provide a capability to write data to the format.

SEDRIS DEVELOPED INTERCHANGE CAPABILITIES

The SEDRIS interchange specification is designed to serve as a standard intermediary between differing representations and formats thereby providing a conduit for interchange. Figure 2 shows how this concept is implemented, for six networked simulations, through use of a standard interface and common data model.

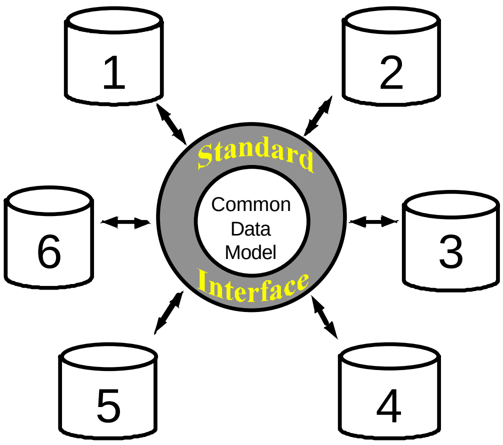

Figure 2. Interchange through SEDRIS

The intent of the development effort is to create one standard method to interchange environmental databases in a consistent fashion across the widest possible range of heterogeneous simulation systems that incorporate synthetic environments. The interchange specification consists of the interchange format, rules for generating compliant transmittals, and the interface description to the data model representation.

The data model implementation is transparent to both producers and consumers. An API efficiently enables M&S systems and producer conversion software to pass data through the data model. The design of the API and transmittal files does not mandate any specific hardware platform dependency. Use of the data interchange format frees the interchange from any operating system dependencies.

Common tools and software are shared and reused, thereby achieving a reduction in conversion/interchange costs. Ad hoc conversions are eliminated. Therefore, there is less opportunity for the loss of significant data leading to correlation problems.

APPLICATION PROGRAMMER'S INTERFACE

The API provides a consistent interface between a software application designed to process the simulated environment data and the underlying SEDRIS transmittal medium. The API uncouples the user's application from the interchange medium's data structures,
allowing the format, its data structures, and the user's application to evolve independent of each other.

The API has been implemented as a layered software model on two levels: Level 0 and Level 1. The routines contained in each level are intended to be linked into a user's native application to provide direct program access to a SEDRIS transmittal.

Level 0 is designed to perform data access with no derivation of data. What was originally provided is what is returned. To accomplish this strictly enforced interface, Level 0 provides a minimal set of fundamental access routines. These routines provide the capability to:

- Open and close a database transmittal
- Find and retrieve an object in the transmittal
- Manipulate objects

Level 0 is technically sufficient to allow complete bi-directional data access with a SEDRIS transmittal.

Level 1 utilizes the Level 0 routines and provides additional routines of a higher level of abstraction. Level 1 routines attempt to supply missing data by derivation if existing data makes derivation possible. Level 1 can be thought of as a small library of specialized applications that provide derived information (e.g., Get the footprint of a specific 3-D model).

Access to SEDRIS transmittal data is context-sensitive to support representational polymorphism. To support user data needs, only the data that fits the context is provided as output or required as input. Contextual retrieval is supported through the capability to define a geographic search boundary within the total area covered by the database, to create a search filter for limiting the type of objects which are examined, and to generate an iterated list of the located objects. The iterated object list represents the contextual constraints specified by the user.

The API Level 0 supports twelve forms of location representation and three forms of color representation. To ensure that conversions are done consistently, the API provides conversion routines to all database providers and users. Level 0 routines let a user select which location representation and color representation is to be applied. Additionally, Level 1 routines are provided to perform coordinate and color derivations for discrete data elements. The twelve supported location 3-D coordinate conversions are:

- Geodetic
- Geocentric
- Geocentric Equatorial Inertial
- Geocentric Solar Ecliptic
- Geocentric Solar Magnetospheric
- Solar Magnetic
- Global Coordinate System
- Polar Stereographic Projected Coordinate System (PCS)
- Lambert Conformal Conic PCS
- Transverse Mercator PCS
- Universal Transverse Mercator PCS
- Local Space Rectangular

The three formats for color representation are:

- Red, Green, Blue
- Hue, Saturation, Value
- Cyan, Magenta, Yellow

SOFTWARE UTILITIES

A set of software tools, based on the standard API, have been developed to aid in viewing, examining, and validating elements of a SEDRIS transmittal. The currently available tools are:

- Depth: Provides a plain text printout of the entire transmittal. Depth is primarily intended for use by producers to debug data relationships. Depth will operate on any platform that supports a C compiler and the Read API.

- Syntax Checker: A plain text program that validates the syntactical correctness of all entries in a SEDRIS transmittal in accordance with the data model. Syntax Checker is intended to aid producers in developing syntactically correct SEDRIS transmittals by reporting and explaining encountered errors. Syntax Checker will operate on any platform that supports a C compiler and the Read API.

- Transmittal Browser: An X-windows-based, point-and-click GUI browser, which presents a hierarchical view of the elements of the data model within any transmittal. Transmittal Browser works in the same manner as a Windows File browser. The initial element is an environment object. Subsequent examination reveals the make-up of the object sub-components: libraries, base, transmittal encoding, accuracy and lineage. Each of these components can be examined in further detail.

- Model Viewer: Provides an Open GL-based viewer for 3-D polygonal models. It can also be used to view 2-D textures. The Model Viewer runs only on UNIX platforms using Open GL and currently supports:

  - Level of detail
  - Articulated components
  - Textures, colors, and lights

- Side by Side Terrain Database Viewer: Runs on an SGI platform (requires a Performer Loader for SEDRIS) and supports the side-by-side viewing of two to sixteen SEDRIS transmittals to visually compare their terrain database elements.

- Vector Product Format Draw: Provides a side-by-side 2-D map presentation of VPF features. This X-windows based program works with VPF-based SEDRIS transmittals.

SUMMARY

The M&S community needs an environmental data representation and interchange mechanism which not only satisfies the requirements of today's systems, but can be extended to meet future data sharing needs. This mechanism must allow for the standard representation of, and access to, existing simulation and operational environmental databases. It must support databases containing integrated terrain, ocean, atmosphere, and space data. Finally, it must allow for the increased utility and reuse of legacy environmental databases, while remaining sensitive to the disparate data representational needs of visual, sensor, and computer generated force oriented simulation applications.

The SEDRIS Project provides environmental data users and producers with a clearly defined interchange specification with the following characteristics:

- Database interchange focused on the reuse of environmental data originally developed for one simulation by another. The interchange specification also supports database access and reuse in networked simulations that exchange data during operation. It supports the full content of the original database and provides for reliable pre-runtime transmission and efficient access.

- Provides a shared view of environmental ground truth to a collection of heterogeneous networked simulations. As a precondition for interoperability, the view of the environment in each simulation needs to be correlated at run-time as exactly as possible (for the given objectives of the simulation federation). This problem is more complex than just data reuse, since different simulations may require significantly different representations of the same environmental ground truth (e.g., textures for image generation versus feature attributes for CGF reasoning). The interchange specification promotes interoperability by carrying a coherent and unified environmental representation that spans the range of simulation environmental data models.

When fielded in 1998, the SEDRIS data interchange specification will support the pre-runtime distribution of source data, three-dimensional models, and integrated databases that describe the physical environment for both simulation and operational use.

The SEDRIS Project URL site is www.sedris.org**.** This site provides one-stop shopping for SEDRIS developer communication with the M&S community. The site includes all SEDRIS Project documentation, software releases, current briefings, an overview development schedule, a calendar of upcoming events, and other items of current interest**.**

Acknowledgments

In addressing a broad spectrum of database interchange issues the SEDRIS Development Project cuts across established U.S. Military Department areas of responsibility. Additionally, the vast majority of knowledge in database interchange issues resides in industry. This situation has necessitated a novel project management approach that focuses government investment and priorities but takes advantage of industry expertise and profit motives. That approach provides DoD oversight, while delegating implementation issues to specific industry partners with both the insight into the problem domain and the ability to effectively implement solutions. The project could not have achieved its objectives without industry involvement.

The U.S. Defense Modeling and Simulation Office (DMSO) has provided project funding, with significant contributions in technical personnel support provided by the U.S. Defense Advanced Research Projects Agency (DARPA) Synthetic Environments Program, the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), and the U.S. Naval Oceanographic Office (NAVOCEANO) and Naval Air Warfare Center - Training Systems Division (NAWC(TSD)).

The Under Secretary of Defense (Acquisition & Technology) (USD(A&T)) des-

ignated M&S Executive Agents (MSEAs), for the authoritative representation of the natural environment, have provided subject matter expertise in reviewing the data model content and are members of the project management team. The environmental MSEAs are the National Imagery and Mapping Agency (NIMA), Department of the Navy, and Department of the Air Force, for terrain, ocean, and atmosphere and space respectively. The designated MSEAs have established the following offices to execute responsibilities: Terrain Modeling Project Office under NIMA, Ocean Executive Agent Office under the Oceanographer of the Navy, the Air & Space Natural Environment Executive Agent Office under the Air Force Combat Climatology Center. The mission of the MSEAs is to enable M&S developers and users to represent their domain areas of responsibility rapidly, thoroughly, authoritatively, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, reuse, and confidence.

Significant contributions in editing and reviewing this paper were made by Richard H. James and Michael R. Welch, Orion Development Group, Inc. of Winter Park, Florida, as part of their task to document the SEDRIS development effort.

About the Authors:

Paul G. Foley is an Information Systems Engineer with the MITRE Corporation and is currently the Environmental Division Chief at the U.S. Defense Modeling and Simulation Office. A retired U.S. Army Corps of Engineers Officer, Mr. Foley has over 25 years experience in topographic operations and digital geospatial systems. He holds advanced degrees in Photogrammetry from Purdue
University and Research and Development Systems Management from the University of Southern California and is a graduate of the U.S. Army War College.

Farid Mamaghani has worked in the field of interactive networked simulation since 1984. He is one of the original designers of the U.S. Defense Advanced Research Projects Agency (DARPA) Simulation Networking (SIMNET) computer image generation system, and has worked as a systems engineer and project manager on a variety of networked simulation projects. He is currently an independent consultant, with clients in both the DoD and commercial sectors.

Dr. Paul A. Birkel is a Multi-disciplinary Systems Engineer with the MITRE Corporation, currently supporting several U.S. Defense Advanced Research Projects Agency (DARPA) projects in environmental modeling, as well as the U.S. DoD Joint Simulation System (JSIMS). Previously he led the development of the U.S. Army standard Mapping, Charting, Geodesy, and Imagery (MCG&I) capability for Command, Control, Communications, Computers, and Intelligence (C4I) systems, known as the Terrain Evaluation Module.

References:

DoD 5000.59-P, Defense Modeling and Simulation Master Plan (MSMP), 17 October 1995

Synthetic Environment Data Representation and Interchange Specification (SEDRIS) Rationale Document, June 1996

Birkel, Paul A., SEDRIS Geospatial Reference Model, July 1997

Mamaghani, Farid, Creation and Usage of Synthetic Environments in Realtime Networked Interactive Simulation, June 1995