

Enterprise Terrain Data Standards for Joint Collective Training

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ABSTRACT

NATO and its nations face a number of historical challenges to generating and sharing modeling and simulation terrain data for training and mission rehearsal: poorly correlated source data; complex processes/tools that perpetuate the dependence on subject matter experts (SMEs) to create/modify data; the need to rapidly change/update databases during event planning to accommodate emerging requirements; pervasive use of diverse proprietary runtime formats; the lack of a web-based repository of authoritative data for users to share and reuse; and classification/releasability issues that inhibit sharing with our mission partners. The primary purpose of this paper is to study these problems from a U.S. Joint training perspective, and identify common requirements and possible solutions that may also be applicable NATO-wide. It will cover the advantages, disadvantages, and potential approaches for adopting a common enterprise terrain database standard/specification. The paper will also explore and compare current terrain data production standards or specifications. Finally the paper will recommend mitigating actions toward providing greater harmonization of terrain databases and their associated creation processes within the training community for the encoding, storage, access, and modification of a representation of the natural and man-made terrain for virtual and constructive simulation applications.

1.0 TERRAIN DATA CHALLENGES FOR JOINT TRAINING

The development of digital, computer-based training simulations/simulators has evolved over the last four decades, in which early approaches were often constrained by severe hardware, software and data source limitations. Simulation engineers were required to make compromises between a simulation or simulators' targeted fidelity and its level of generality, scalability, abstraction, and correlation with other systems. Community-wide standardization could not be achieved because technologically viable solutions only offered partial solutions to training needs. Consequently, Joint and Service simulation training capabilities adopted or developed differing standards, often in isolation, tailored to their specific training needs. This has resulted in recurring costly, manpower intensive integration efforts to link these disparate simulations together in training federations to meet joint training requirements. Digital technologies have made tremendous strides in the past decade and are closing the gap between what is required for training and what technology can now deliver. With the U.S. Department of Defense's (DoD) direction to move modeling and simulation (M&S) capabilities to the DoD Information Technology (IT) Enterprise Framework, the time is right to leverage these strides and transition the U.S. Joint training enterprise toward a smaller set of common standards and better investment of our scarce resources towards common solutions.

Terrain database construction remains a time-consuming, manpower-intensive process. The wide variety of storage and (often proprietary) runtime formats makes it difficult to transfer terrain data between simulations,

increases support costs, and limits reuse. Capabilities utilizing proprietary specifications are prone to being “locked in” to a specific technology and/or vendor. There is a lack of an easily accessible storage capability that includes metadata and validation data for each product and incorporates safeguards necessary for the protection of classified data to enable discovery and reuse by other users with similar requirements. All these factors contribute to high terrain data production costs and hinder our ability to easily reuse existing data products.

The Joint training community has faced a number of historical challenges to terrain generation, including:

- Duplicate and poorly correlated source data.
- Dependence on subject matter experts (SMEs) to create and modify terrain data and the need to rapidly change databases during the event planning cycle to accommodate emerging training requirements.
- Most simulations and simulators utilize application-specific, proprietary runtime formats. The wide variety of runtime formats makes it difficult to transfer terrain data between simulations, increasing support costs and hindering reuse.¹
- Lack of a web-based repository of authoritative training data for users to share and reuse existing terrain datasets and databases, to include a cross-community configuration management (CM) structure to inventory holdings.
- Requirements for short terrain development timelines to support mission rehearsal.
- Difficulty in sharing terrain data with Coalition partners, who more commonly utilize open, international standards. This is compounded by policy issues that restrict release of classified source data or limited distribution (LIMDIS) material.

The objective of this paper is to study these problems and identify requirements and possible common solutions for the encoding, storage, access, and modification of terrain databases for simulation applications.

2.0 ADOPTING A COMMON ENTERPRISE TERRAIN DATABASE STANDARD

Terrain databases are created through a costly and time-consuming authoring process resulting in very large platform-dependent databases that often support single applications. During this production process, data from various sources and formats is collected, managed, validated, harmonized, referenced, attributed, decimated (sometimes intensified), and then published to the simulation application(s). Conversion of one system's data to another format is based upon rigidly defined data format specifications for both the source and target system. Differing proprietary data formats require the development of a customized data converter software application to accomplish each conversion. These point-to-point solutions are expensive, time consuming, and often unreliable. Specific target system implementation needs usually require the converted data undergo several additional conversions before a useable runtime 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. A study conducted by the US Joint Training, Integration, and Evaluation Center in 2010 identified 93

¹ While databases used for daily simulator training events at the Tier 3 and 4 levels are reused on a repeated basis, constructive terrain databases at the Tier 1 and 2 levels are commonly built for a single purpose and infrequently reused.

different types of geospatial data² used in Live, Virtual, & Constructive (LVC) simulations with 10 different active standards and mediation formats in use by the M&S community (Morse, K., et al., 2010). Development and maintenance of these conversion software modules can quickly become cost-prohibitive.

There are a number of advantages and disadvantages to consider in maximizing adoption of a common enterprise terrain database standard or specification:

2.1 Advantages

- Improved ease of constructing and correlating synthetic environments and making rapid updates/changes to the synthetic environment databases supporting training and mission rehearsal requirements.
- Improved data interoperability between federates and/or services within complex training systems. Databases conforming to the standard or specification can be more easily reused as well as interchanged and shared between end users.
- Reduced data configuration management workload.
- Reduced costs and shortened production timeline for database development by eliminating redundant implementation work. If the synthetic environment database can be shared in an enterprise distributive mission training/operation event and also used as both a storage format and a runtime format, time and labor costs are essentially eliminated for off-line data compilation into proprietary simulation client data formats (assumes client conversion to use databases structured in accordance with the standard or specification).

2.2 Disadvantages

- Converting existing data to the new standard or specification may result in data corruption, missing data or data loss.
- There may be technical compatibility issues that make transition infeasible or inordinately time consuming and costly to implement.
- Transition to a new standard or specification may pose possible risk of extended downtime and operational impact to the organization. This is ameliorated somewhat, in that software programs usually have separate development and production (operational) baselines; however, the transition may result in a longer than usual development period.
- Development costs associated with adapting training simulations, simulators and tools to use databases constructed in accordance with the new standard or specification.

² Of the 93 data formats, 80 were actively maintained. Thirteen of those formats were not strictly data storage formats, but were included as they were data dictionaries or conceptual models without which several important storage formats could not be implemented. Of the remaining entries on the list, four were GIS extensions to major relational databases, 71 were unique storage formats, and five were Service- or Department-specific “universal” geospatial databases. Ten of the storage formats and 10 of the conceptual models were identified as mediation formats.

2.3 Approach

Given these circumstances, there are two approaches that could be followed in establishing a common enterprise database standard or specification:

- (1) Establish a common standard or specification for only offline data storage—This approach would provide the benefits of data interchange and reuse, but would still require offline recompiling of the data into each client application’s runtime format.
- (2) Establish a common standard or specification for both offline data storage and runtime applications—This approach gains additional benefits in eliminating costs associated with recompiling into runtime formats. However, in today’s constrained fiscal environment, any decision to move to a dual-use open, common terrain database standard or specification for the training enterprise must weigh the operational advantages of doing so against the opportunity costs and operational impacts. The circumstances for each simulation/simulator system will vary and must be individually assessed.

3.0 ANALYSIS OF TERRAIN DATABASE STANDARDS OR SPECIFICATIONS

3.1 Data Production for Training/Exercise Events

High level processes used across the community in building terrain databases are similar with subtle differences between components in the following steps:

- **Identify terrain data requirements/sources** – This requires some preliminary actions by the event owner to define the scenario parameters/scope and the required data elements for the baseline, to include the simulations/federation to be used.³ This enables identification of terrain data requirements and determination of desired data sources for query.
- **Gather required data** – These source data products come largely from (but are not limited to) government sources like the National Geospatial Intelligence Agency (NGA) and the National Reconnaissance Office (NRO). Based on defined requirements, catalogs are searched and existing datasets and databases meeting criteria are downloaded. Where authoritative data sources are not available, terrain data products are generated from imagery, field collection, databases, etc. as required.
- **Process and refine the data** – Using geospatial software, correct errors; add detail; correlate features, elevation, and imagery with other data in the baseline; and add required 3D models. There is consensus that the process and refinement stage constitutes the majority of the time and labor costs involved in producing a terrain database. Conducting error correction and correlation at the authoritative data source (e.g. NGA, NRO, etc.) would greatly alleviate the burden on Joint and Service trainers and other communities. The ability to get geo-referenced and orthorectified imagery (along with color correction and seasonal matching) from authoritative sources would be a great gain for all using communities.

³ This example is typical of a Joint training event. Tier 3 and 4 simulator training define required databases/terrain off daily or deployment training needs, OPLAN requirements, etc., and are not usually driven by a larger, specific event.

- **Post-Process the data** – The structure and level of detail for the dataset is established and compiled to form the required runtime database for the simulation application(s) to be used. This step also involves exporting the data as required and saving to the appropriate repository.
- **Test** – The database is loaded into the simulation/simulator and tested in runtime. Problems discovered during testing are corrected in the baseline and saved.

3.2 Foundational Attributes

The following criteria was used in the comparison of candidate standards/specifications:

- (1) **Utilize open, evolving, publicly available, published standards that are platform independent.**
Reasoning: Adoption of an open, national/international standard would provide end users direct access to the specification and allow its further development through an open, participatory process. If open standards are followed, applications are easier to port from one platform to another since the technical implementation follows known guidelines and rules, and the interfaces, both internal and external, are known. As a result, there will be improved data interchange and exchange. If guidelines are followed, open standards offer better protection of the data files created by an application against obsolescence of the application. This is especially beneficial with respect to organizations that possess huge amounts of data stored electronically. Open standards are less prone to being “locked in” to a specific technology and/or vendor. While adoption of open, publicly available standards is not mandatory, it is highly desirable since other specifications and non-accredited standards that are not open tend to fulfill only specific requirements of specific users and do not benefit from community input. This limits wide adoption and thus the underlying value of an open database standard and the notion of reusability. The use of open international standards is also more amenable to use by our mission partners.
- (2) **Support runtime applications and source data storage.**
Reasoning: Such a dual-use standard or specification may reduce the time and labor costs required for simulation terrain production, since there is no need to recompile into a specific simulation runtime format (assumes client conversion to use databases constructed in accordance with the standard or specification). It reduces data storage requirements, reduces the loss of correlation resulting from the compilation process, avoids complexity in configuration management, and yields a more efficient update process. The shorter production to runtime time constraints are of particular value to organizations with short-cycle mission rehearsal needs (e.g., Special Operations Forces).
- (3) **Allow rapid data access for concurrent multiple simulations and services.**
Reasoning: Standard or specification storage structure is optimized for simulation/simulator/service client runtime performance and promotes efficient, real-time, simultaneous data access by all participating client devices. This optimized storage structure also permits flexible and efficient updates due to the different levels of granularity with which the information can be stored or retrieved.
- (4) **Allow simulation clients to modify the terrain data store while the simulation is running during an exercise/training event.**
Reasoning: Supports the user’s ability to quickly modify the terrain and 3D models during runtime to correct discrepancies found in testing or accommodate the accomplishment of training objectives during an event. The use of such a dynamic editing capability would necessarily be controlled by a training event authority (e.g., Exercise Director) to avoid corruption of the database or disruption of the event.

- (5) **Support dynamic terrain and revision history (i.e., allow deformation of the terrain and 3D objects).**
Reasoning: Necessary for accurate representation of the effects of modeled actions (e.g., weapon effects, weather effects, and actions of modeled entities) on the terrain (e.g., rubble buildings, poor trafficability due to precipitation, and digging of tank trenches).
- (6) **Support procedural geometry (e.g., procedurally generate ground textures from raster material layers).**
Reasoning: Ability to support the generation of realistic, highly detailed objects and textures enables the terrain builder to automatically create large amounts of content with smaller file sizes and reduced labor.
- (7) **Support global coverage with multiple levels and layers of detail (i.e., capable of storing very high resolution data).**
Reasoning: Necessary for high spatial resolution and scalability, a terrain database that can provide multiple levels of detail in a hierarchical structure provides an efficient means to organize synthetic terrain data and allow access to the information at the required detail level. Multiple layers (e.g., vectoring data, material coding, and light sources) are necessary to support sensors and other simulated functions.

3.3 Candidate Standards/Specification Initiatives

The following Terrain Database initiatives were investigated as candidates:

- (1) **Master Database (MDB)** – Developed and used specifically by the U.S. Army Program Executive Office for Simulation, Training and Instrumentation (PEO-STRI) Synthetic Environment Core (SE Core) program. MDB defines the central repository for the creation of correlated databases used to train, mission plan, or mission rehearse in the LVC domains. MDB supports the ability to store common standard source data that is configuration managed, quality assured, and correlated in a format usable by multiple vendors and products.
- (2) **NAVAIR Portable Source Initiative (NPSI)** – Developed by US Naval Air Systems Command (NAVAIR) and used specifically by the U.S. Navy. NPSI provides database reuse across Type/Model/Series platforms to lower the life cycle cost of out-the-window visual terrain, 3D models, and sensor databases, and adds dataset archive capability and short-notice distribution services. The metadata and metadata architectures are used to facilitate data discovery, data understanding, and effective data distribution. The metadata is also employed for NPSI dataset archiving and distribution.
- (3) **Air Force Common Dataset (AFCD)** – Derived from the NPSI specification and used specifically by the U.S. Air Force. AFCD was developed to help improve database cost/schedule/performance and reduce correlation differences among Air Force simulation programs. AFCD references common commercial formats developed and used by industry and adopted by the Government. This approach does not favor any single source supplier of databases or database toolsets; and

focuses on commercially defined interfaces in interim format files, rather than mandating the runtime product.⁴

- (4) **CDB (formerly Common Database)** – Used by U.S. Special Operations Command (USSOCOM), U.S. Marine Corps, Joint Staff J7, the NGA Foundation GEOINT 3D initiative, and 13 foreign partners. CDB is an Open Geospatial Consortium (OGC) Standard (CDB 1.0) adopted Sept. 23, 2016. The CDB synthetic environment represents the natural environment including external features such as man-made structures and systems. It encompasses terrain relief, terrain imagery, three-dimensional (3D) models of natural and man-made cultural features, 3D models of dynamic vehicles, the ocean surface, and the ocean bottom, including natural and man-made features on the ocean floor.

3.4 Standard or Specification Comparison

The Comparison Matrix in Attachment 1 provides the summary analysis between the four initiatives, which is summarized below:

- The standard/specifications vary in their scope, breadth, and depth; but fulfill the data production and/or data format requirements of their respective users. However, they are too diverse to support a common enterprise data repository without the addition of format translation capabilities.
- The standard/specifications use established geospatial source data and industry standards. Common among the initiatives were TIFF, GeoTIFF, OpenFlight, Shapefile, DTED, JPEG, and JPEG 2000. Note: CDB can read the DTED, but saves the data in GeoTIFF format.
- Although there is a great deal of similarity among the standard/specifications with regard to the data standard formats used, shapefile attributions differ and present an obstacle in harmonizing databases. Shapefile attributions are user-defined and not constrained by the format, which creates complexity and increases the difficulty in mapping data models.
- CDB is the only one of the four that has been vetted by an international standards body (OGC) and has been approved as an open, accredited standard.
- Most database formats serve only as a storage format and require a full offline re-compilation of the database into a (usually proprietary) simulation runtime format. The CDB standard is unique in that geospatial data structured in accordance with the standard can serve as both an offline storage archive and as a runtime format for simulations/simulators that can directly publish CDB.
- All four use the WGS-84 Earth Model as a reference coordinate system, which has gained universal acceptance within the GIS community as the preferred method for defining where objects exist on the earth.

3.5 Reuse and Interoperation of Environmental Data & Processes (RIEDP) Study

This study reviewed the Simulation Interoperability Standards Organization (SISO) RIEDP Final Report (October 2012), which also reviewed the MDB, NPSI, AFCD, and CDB initiatives; as well as the French Air Force

⁴ AFCD and NPSI use the notion of dataset to designate a set of environmental data used and/or built by database producers during their database generation process excluding the target application level data that they call a (runtime) database. This includes data resulting from the operations of refinement, reconciliation and possibly integration of source data (RIEDP Study Group Final Report, 8 October 2012).

community Sogitec/Thales, UK Ministry of Defence (MoD), and German Rheinmetall initiatives. This study agrees with RIEDP Study findings that the four candidate specifications/standards:

- Use the same core geospatial source data formats.
- Use the same high level database generation process flow with the same stages.
- Show similarities between initiative data models, which was expected given heavy reliance on commercial-off-the-shelf (COTS) products and de-facto or standard formats.
- However, data models diverge along the stages of each process, particularly in the use of feature dictionaries, attribute definitions, and the attribution rules. This divergence complicates data reuse between initiatives, and even impedes it, if the data models cannot be “interfaced.”

Potential areas of convergence/divergence between candidate initiatives:

- **Source data formats:** using the same source data formats may not be sufficient to allow a full convergence.
 - Raster formats (e.g., DTED, GeoTiff, and JPEG2000) can be good enough for convergence and conversion tools exist between all these formats.
 - However, Shapefiles format with its user-defined attribution schema can lead to divergence.
- **Layers:** The basic layers (elevation, features, texture, 3D objects) are commonly shared, with similar formats amongst the initiatives; but layer content, detail, and resolution may be different for specific purposes and must be looked at closely.
- **Tiles:** There is a great variety of requirements among the initiatives, from the “no specific tile size” (AFCD approach) to the CDB fully defined tile schema. Tiles can be adjusted at any time using the GIS tools capabilities; so this is not a main technical issue, but does have a cost.
- **Internal format:** Pertains to the aggregation of the data from the layers to produce a desired “integrated database.” This primarily involves the definition of library of object classes and the linkage of these with the object instances.
 - Depending on the initiative, the notion of “integrated database” may or may not make sense. For instance, AFCD’s scope did not cover this notion, leaving it to the responsibility of the simulation database provider (who receives the AFCD data).
 - At the opposite end of the spectrum, MDB, and CDB initiatives had integrated databases, but with significant differences in their internal formats, reducing database reusability and impacting the correlation of the database generation results at the target application level.
- **Dictionary:** The initiatives do not use the same dictionaries, often using terms or concepts that are not covered in the various standard dictionaries. This results in each initiative defining a specific dictionary for their own purposes.
- **Attribution:** Environmental data is often generally derived from GIS data, with specific simulation requirements integrated via a set of attributes associated with various features. The use of Shapefile format with its user-defined attribution schema can lead to divergence. While mapping can be used to allow unambiguous exchange of environmental data between initiatives using different dictionaries, this mapping principle may not suffice with regards to attribution rules associated to specific modeling of the environment, as the complexity from semantics remains. For example, the RIEDP Study found that an attribute may:
 - Be relevant to different entity types (for instance point, linear or areal features) and/or;
 - Be used at different abstraction levels of the data model (for instance Feature Class level or Feature Instance level) and/or;

- Have different ranges of values and/or;
- Refer to a sub-model, more or less complex, allowing flexibility in the extension of the data model.

The notion of attribution involves the concept of a data model. Comparing the data models adopted by each initiative, the attributes and attribution rules (governing how such features and components may be attributed) were different among the initiatives and were the most significant divergence area.

The RIEDP Study Group determined that attribution issues and dictionary were the most important sources of discrepancies between initiatives and the most likely areas to focus standardization efforts.

3.6 Emerging Capability — Geospatial Repository and Data (GRiD) Management System:

GRiD is becoming the NGA’s 3D high resolution enterprise-level environment data portal for point clouds, elevation models and high-resolution 3D content. It is designed to store, process, visualize and disseminate a variety of geospatial datasets, such as 3D point cloud data (e.g., Light Detection and Ranging (LiDAR)) and associated co-collected 2D geospatial products (e.g., digital elevation model (DEM), Electro-Optical (EO) imagery, etc.) By the close of 2018, GRiD will be producing and serving high resolution 3D synthetic modeled content, including roads, trees, buildings and more. GRiD will serve as the central repository for NGA’s Foundation GEOINT 3D (FG3D) capability. FG3D will export data products in CDB format. The figure below illustrates the concept. One option to explore would be to leverage GRiD as a repository for simulation-ready environment data for training.

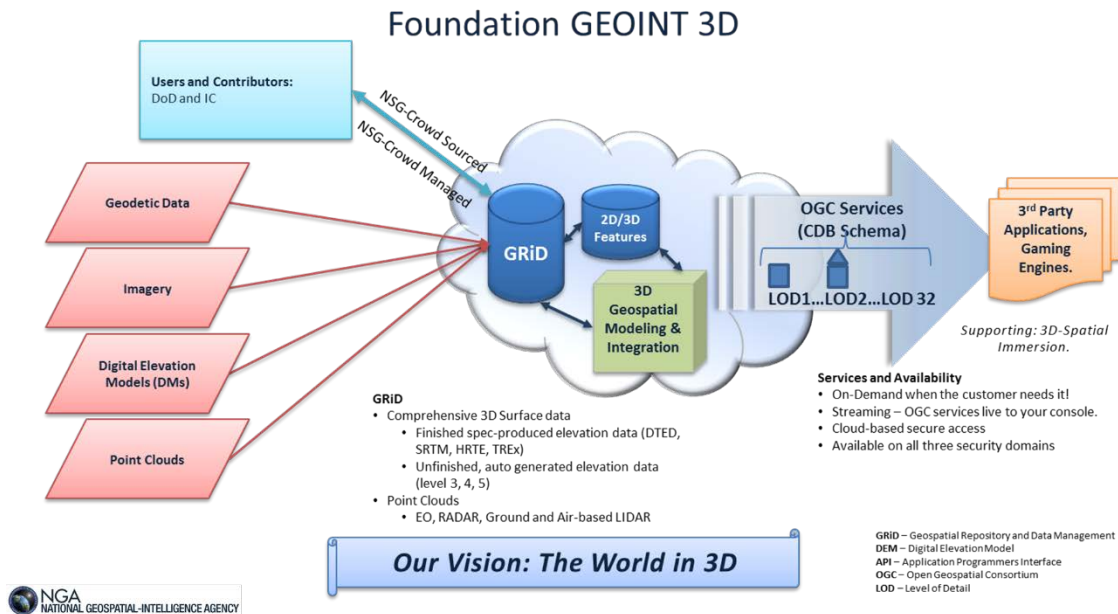


Figure 1

3.7 A Case for CDB as a Joint Training Enterprise Standard

As a potential candidate, the CDB standard offers a number of attributes favorable to adoption, since it:

- Has become an open OGC international standard.
- Serves as both a storage medium as well as a non-proprietary runtime format.
- Does not explicitly mandate the use of specific computer platforms and system software; as a result it can be implemented on existing platforms.
- Has an internal data representation model based on open industry standard native source data formats, including TIFF, Geo-TIFF, OpenFlight, Shapefile, and JPEG/JPEG 2000 – all of which are used by the Joint training community.
- Defines content necessary to support simulator client-devices; including visual systems, sensors such as forward looking infrared (FLIR) and night vision goggles (NVG), radar/laser reflectivity, computer-generated forces, and weather simulation.
- Follows Distributed Interactive Simulation (DIS) (DIS) protocol entity enumeration conventions, permitting CDB-compliant moving models to seamlessly integrate with a DIS-compliant simulator.
- Is scalable and can be built to a size or a density that far exceeds the capability of current and future client devices. CDB can be scaled to take advantage of future simulation/simulator technological improvements.
- Is structured with multiple Levels-of-Detail (up to 34) and tiled in such a manner as to promote efficient storage, access, and transportation. Tiles / features are located / oriented using WGS-84 coordinates.
- Supports dynamic terrain and procedural geometry.
- Provides users the ability to store different versions of a CDB database in multiple locations (e.g., classified imagery can be placed in a separate version and stored using appropriate security protocols as required by data sensitivity).
- Is already used by 3 of 6 owners of simulation capabilities in the Joint training community.
- Is used in offline database creation capacities for legacy simulators without runtime publishing capability, including converting NPSI datasets to CDB format.
- Is being evaluated within the special operations community in the following simulators for possible use of CDB runtime publishing:
 - 160th Special Operations Aviation Regiment (Airborne) (SOAR(A)): MH-60, MH-47 and MH-60M
 - AFSOC: AC-130U, MC-130H, AC-130W, CV-22, and U-28
- Is used by NGA's Foundation GEOINT 3D initiative as an export format.
- Is used by UK MoD (100+ terabytes of CDB data); and 12 other countries have used the specification to support multiple simulator platforms.

4.0 RECOMMENDATIONS

The following mitigating actions are recommended toward promoting greater harmonization of terrain databases and their associated creation processes within the United States Joint training community. These recommendations in many ways mirror those of the RIEDP Study Group

4.1 Near term actions (CY2018)

- (1) **Identify and consolidate enterprise environmental data requirements for Joint training as a baseline for follow-on actions.** During the analysis, it was determined that the community had not gathered or formalized their requirements. This effort should comprehensively identify all aspects of environmental data needed for simulation and simulator support to training, exercise, and mission rehearsal including, but not limited to, training tiers, missions, platforms, weapons, and sensors.
- (2) **Establish a more consumer-centric, web-enabled storage of terrain data to shared spaces for user access.** Data would be fully visible, searchable, accessible and understandable, except when limited by security, policy, or regulations. This would require metadata “tagging” of all data (intelligence, non-intelligence, raw and processed) to enable authorized discovery by known and unanticipated users in the enterprise. This effort would provide data in two categories:
 - Source data from authoritative providers that has been “preprocessed” to correct errors and facilitate correlation and seasonal color matching of data layers.
 - User community databases produced for simulation or simulator use made available through a discovery cataloging system with links to the appropriate storage site.
- (3) **Participate in the open, consensus-based environment data standard development process.** In order to posture the Joint training community for adopting a common database standard or specification for the training enterprise, increase the community participation in current open, consensus-based standard development processes in order to address any shortfalls in current candidate standards/specifications (e.g., multispectral sensor support) that inhibit compatibility with Service/Agency capabilities.

4.2 Mid-term actions (CY2021):

- (1) **Support SISO in developing a common, detailed environmental features description.** This entails identification of object instances and classes (such as features, 3D objects, and textures) within the common library, the choice of semantics and mapping with existing dictionaries, and the linkages/semantics between instances and classes. The follow-on RIEDP Product Development Group (PDG) proposed two products for SISO adoption (SISO-PN-007-2013 V1 of 22 April 2013) consisting of:
 - An Environmental Data Model Foundation, which will serve as a SISO Guidance document. The data model would be composed of two tightly coupled parts, the Reference Process Model (RPM) and the Reference Abstract Data Model (RADM). These form the foundations for existing and/or emerging database generation projects to compare, contrast, and map their data generation process and data model capabilities to these models.
 - An Environmental Detailed Features Description, which will be a SISO Standard product. The description will provide the required information for identifying instances and/or classes of environmental features and objects that, along with their specific attributes, value ranges,

and metadata, will be utilized in environmental data products. This description will ensure data interoperability through the identification of features, their definitions (through the use of standardized dictionaries), their corresponding attributes, and any associated metadata.

Both products may improve reuse and interoperability of environmental data and processes; and the training community may benefit in participating in the development of the standard as applicable toward accomplishing this action.

- (2) **Establish a consensus on attributes and attribution rules for the training community.** Preferably, an existing attribution schema suitable to training, exercise, and mission rehearsal would be used, rather than developing one unique to the training community. Initially, this would involve the identification of a common list of features and attributes (concept, range of values, application domain), using standard dictionaries, to be associated to the environmental objects (classes and instances). In the long term, identify and define common attribution rules for the community.

4.3 Long term actions (CY2021 - 2024):

- (1) **Migrate the Joint training enterprise toward adoption of a common database standard or specification where it will not adversely affect cost, schedule, or performance.** Ideally, this should be an open, national or international standard that can be used for both offline data storage and as a runtime database format. Enterprise adoption can be phased to minimize impact:
 - (a) **Phase I: Establish a governance/management framework** – Selection of a common database standard or specification should be a consensus-based enterprise decision. Therefore a process should be formalized for selecting and managing the changes to the Joint training enterprise common database standard via an open, community-based process.
 - (b) **Phase II: Common offline storage format (by CY2021)** – As a cost deferment, a common database standard or specification can be initially utilized for offline storage only to avoid the expense associated with adapting existing legacy simulations, simulators, and support tools to utilize the standard or specification natively.
 - (c) **Phase III: Transition constructive simulations to the common standard as a runtime format**
 - i. New U.S. Joint, Service, and Agency enterprise constructive capabilities should, when it meets requirements, develop to the common database standard or specification so as to utilize it natively and accrue the data interoperability and processing benefits.
 - ii. Utilization of a common database standard or specification as a runtime format for legacy systems will require further study to determine the best course of action. Decisions must be based upon mission needs, cost-effectiveness and return on investment, and must consider when various simulations are projected to phase out or whether they have gone into sustainment, since these older systems may not have the resources or the technical compatibility to shift to a new common database standard or specification.
 - (d) **Phase IV: Transition tactical simulators to the common standard as a runtime format**

- i. Service and USSOCOM enterprise tactical simulator capabilities should, when it meets requirements, develop to the common database standard or specification so as to utilize it natively and accrue the data interoperability and processing benefits.
 - ii. As with constructive capabilities, utilization of a common database standard or specification as a legacy simulator runtime format will require further study to determine the best course of action, and any shift must be based upon mission needs, cost-effectiveness and return on investment. Sustainment and acquisition policy issues also apply.
- (e) **Phase V: Modify the common standard to meet unfulfilled requirements** – It is recognized that a common standard may not completely fulfill the requirements of every system/platform in the enterprise. However, enterprise users should not reject the common standard objective until efforts have been attempted to modify the common standard to address any shortfalls (e.g., multispectral sensor support) that inhibit compatibility with Service/Agency capabilities.

5.0 CONCLUSION

The U.S. Joint Staff Director for Joint Force Development (J7) training provided guidance for Combatant Commands, Services and Agencies to partner in advancing Joint interoperability: cooperatively develop and evolve toward an agreed-upon set of standards in order to achieve effective, cost-efficient and timely solutions for education, training, exercises, and mission rehearsal. Common standards and an enterprise approach will enable the organization, development, management, and integration of DoD capabilities that provide effective and efficient information exchange. The time is right for the Joint training community to partner, to include our Allies, in moving toward establishing enterprise standards and common solutions for the encoding, storage, access, and modification of terrain databases for simulation applications.

These agreed-upon enterprise terrain standards/solutions should guide development, and to the greatest extent feasible and appropriate:

- Utilize public or commercial standards available through domestic and international private sector standards organizations, or existing federally developed standards, rather than develop new standards to meet capability needs.
- Avoid propriety solutions that increase the cost of development, management, and operation.
- Strive to eliminate redundancy and reduce the number of standards to the minimum required for efficient operation.

Bottom line, the community would benefit from reduced integration requirements and costs of building bridges/translators due to different/proprietary formats, and the increased ability to share and reuse of data.

DISCLAIMER

The views and conclusions contained in this document are those of the author(s) and should not be interpreted as representing the official policies, either expressed or implied, of the US Joint Staff or the US Government.

This paper or presentations associated with it, are not to be construed as an official agreement to share technical solutions at this time. Approaches presented are being explored and are in the early stages of being realized. As maturity level of the effort increases, partnerships and mutually supporting efforts will be explored.

6.0 REFERENCES

- 1) Morse, K., et al., (2010). “Live-Virtual-Constructive Architecture Roadmap Implementation, Common Capabilities - Common Data Storage Formats Implementation Plan”. Technical Report for the Joint Training Integration and Evaluation Center. Maryland, USA.
- 2) Nadeau, Bhalla, and Hebert (2012), “Streamlining the Deployment of GIS Data for the Synthetic Environment (SE) Generation Pipeline,” at:
http://www.edstechnologies.com/Mailer/july12/PF_6.pdf
- 3) Open Geospatial Consortium (OGC), <http://www.opengeospatial.org>. Last access March 15, 2017.
- 4) Simulation Interoperability Standards Organization (SISO), (2012), Reuse and Interoperation of Environmental Data and Processes (RIEDP) Study Group Final Report (SISO-REF-043-2012).
- 5) Simulation Interoperability Standards Organization (SISO), (2013), Product Nomination for Reuse and Interoperation of Environmental Data and Processes Product Development Group (RIEDP PDG) (SISO-PN-007-2013)
- 6) Waldhauser/U.S. Joint Staff J7, Thomas D, LtGen, USMC. “Joint Training Interoperability.” Received by U.S. Combatant Command, Services and Agencies, 3 June 2016.

Organization	Terrain Generation Capability	Specification	Specification Category	Source Data Repository	Runtime Publishing Format	Standardized Schema & Attributes	Platform Independent	Operating System Independent	Transport Protocol Independent	Utilizes WGS-84 Earth Model	Geospatial Source & Industry Formats Utilized by the Specification												
											TIFF	DTED	Geo-TIFF	OpenFlight	Shapefile	RGB/RGBA	JPEG	DDS	DXTn	FXTn	JPEG 2000	XML	GeoPackages
JS J7 Marines SOCOM	Terrain Generation Service (TGS) & SOFPREP	Common DataBase (CDB)	Open International Standard 6	Yes	Yes	Yes 8	Yes 9	Yes 9	Yes 10	Yes	Yes	Yes 5	Yes 4	Yes 3	Yes 1	Yes 1	Yes 1	Yes 1	Yes 1	Yes	Yes	No 2	No 2
Army	Synthetic Environment Core (SE-Core)	Master Database (MDB)	Government Standard 7	Yes	No	Yes 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	Yes	No 11	No
Air Force		Air Force Common Dataset (AFCD)	Government Standard 7	Yes	No	Yes 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes 1	Yes 1	Yes 1	Yes 1	Yes 1	Yes		No	No
Navy		NAVAIR Portable Source Initiative (NPSI)	Government Standard 7	Yes	No	Yes 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes 1	Yes 1	Yes 1	Yes 1	Yes 1	Yes	Yes	No	No

Notes:

- Included in the OpenFlight texture pattern formats.
- Expected in CDB Version 2 release.
- CDB V2.0 may replace Shapefile format with other OGC formats, e.g. Geopackage.
- CDB V2.0 may replace OpenFlight with other OGC formats, e.g. CityGML.
- CDB can read DTED, but stores the data as a Geo-TIFF.
- CDB has undergone an 18-24 month vetting by an international standards body (OGC) and has been adopted as an open, accredited standard (CDB 1.0) on September 23, 2016.
- Service-specific.
- While all four specifications have standardized schema and attributes, CDB is the only specification that has been vetted by an open international standards body and has been approved as an OGC standard.
- The constraints imposed by the CDB Specification are minimal and are designed to allow its implementation on any of the widely available computer hardware platforms, operating systems, file systems and transport protocols.
- CDB is the only specification of the four that is structured with multiple Levels-of-Detail (LOD) and tiled in such a manner as to promote efficient storage, access, and transportation. The CDB Specification also prescribes the use of an industry standard compression algorithm for its storage intensive raster imagery datasets. This not only provides a substantial reduction in storage, but also reduces the data transmission bandwidths associated with simulator's access to the synthetic environment database at runtime.
- SE Core is pursuing Geopackage as the replacement for Openflight and Shapefiles.

For the purposes of this paper, the following definitions are provided:

- **Accredited standards** – generally have two important characteristics. They are developed and adopted as standards through an open consensus process, under the guidelines of national or international standards bodies (ISO, SISO, IEC, ANSI, OGC, etc.). These procedures ensure that the concerns of all interested parties are heard and addressed. In addition, accredited standards tend to distinguish more clearly the difference between requirements (normative elements) that must be met to conform to the standard, and descriptive material (informative elements) that provide additional information, but do not contain requirements. Accredited standards are publicly available from the respective standards bodies.⁵
- **Industry specifications** – often take the form of formalized industry practices. These specifications generally are developed by a group within the industry, but there are no formal guidelines or procedures that ensure the work is open to any interested party or open to review and comment during the development process. Such groups are not bound to consider or respond to comments on the work. However, such publications are generally publicly available and can be referenced in accredited standards.⁶
- **Attribution** – the assignment of properties to an object class or an object instance describing the environment. Attributes can be included explicitly by direct attachment to the object or instance, or implicitly by inheriting down a hierarchy tree. Attributes can be simply defined by attribute names and their value, or defined by more complex schemas, called attribution rules.
- **Authoritative Data Source** – a recognized or official data source with a designated mission statement, source, or product to publish reliable and accurate data for subsequent use by customers. An authoritative data source may be the functional combination of multiple separate data sources.⁷
- **Dataset** – Simply speaking, a dataset is a collection of data. For the purposes of this paper, a dataset will refer to mid-processed layers of data that are correlated and later compiled to form a runtime database for a specific application. This includes data resulting from the operations of refinement, reconciliation and possibly integration of source data.
- **Dictionary:** The terms, labels, and concepts that allow the data providers to designate and/or describe the features and components of the environment and their attributes.
- **Environmental Database** – refers to the sets of geospatial data and all related data required for modeling and simulation of entities and sensors. The production of an environmental database starts from source data (see definition below) up to the generation of target application databases, also called runtime databases.
- **Internal format:** Pertains to the aggregation of the data from the layers to produce a desired “integrated database.”
- **Source Data** – is used in internal data generation processes to produce one or more final products (usually) specific to a particular set of applications, clients, or systems. Terrain source data refers typically to the raw geospatial data used to produce the terrain database. The main categories of source data are the imagery, the elevation, cultural and manmade vector feature data, and 3D models. The source data are stored and exchanged in source data formats widely used by Geographic Information System (GIS) community.

⁵ Derived from the Association for Suppliers of Printing, Publishing and Converting Technologies (NPES) Standards Bluebook 2013, <http://www.npes.org/Portals/0/standards/pdf/Bluebook2013.pdf>.

⁶ Ibid.

⁷ DoDI 8320.03 of 4 November 2015, Unique Identification (UID) Standards for Supporting DoD Net-Centric Operations
