Agile Terrain for Integrated Simulation and C2 Using Open Standards

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ABSTRACT

Simulation Terrain Data Bases in the US Army often use unique standards that are not compatible with many of the advanced commercial terrain products being developed by industry (e.g. Google Earth). The US Army Simulation to Mission Command Interoperability Overarching Integrated Product Team (SIMCI OIPT) Geospatial Initiative has been working to synchronize Terrain Data for Army Command and Control (C2) and Simulation systems. Generating the terrain data for training Simulations (and C2 Systems) is extremely expensive, requires extensive lead-time and lacks agility. Both the Simulation and C2 Communities have their own unique terrain data standards, however C2 systems are moving toward, and starting to adopt, new and emerging Open Standards used by industry.

This paper will focus on identifying Open Standards that can be used by both communities to represent geospatial information and also stream geospatial data via web services to client applications. We provide an overview of the common (and not so common) geospatial standards for 1) Data Content, 2) Metadata, and 3) Services. We examine the current and future use of these standards for transmission, analysis, and presentation of geospatial data. Open Standards such as Web Map Service (WMS) and Tile Map Service (TMS) for elevation and imagery, and Web Feature Service (WFS) and Geospatial Data Abstraction Library (GDAL) Simple Features for feature data will be included. We also analyze the open source libraries and tools that use these standards, such as the Geospatial Data Abstraction Library (GDAL) from the Open Source Geospatial Foundation. The adoption of advanced commercial terrain products by the Simulation and C2 Communities would be invaluable for improving the agility and interoperability of terrain data for the Warfighter, as well as make available petabytes of potential data sources that can be used in the terrain database generation process.. Recently, the SIMCI Geospatial Initiative has facilitated a Simulation Working Group under the US Geospatial Intelligence Foundation to work with Industry to determine Geospatial Open Standards for the M&S Community.

ABOUT THE AUTHORS

Thomas Stanzione is the Principal Scientist of Technology Solutions Experts, Inc. Mr. Stanzione is an expert in Geospatial data and processes, as well as Open Standards for Terrain. Mr. Stanzione has over twenty five years of experience in modeling and simulation, particularly distributed simulations and computer generated force (CGF) applications, simulation software development, and system integration. He was the principal investigator and program manager for the Army Geospatial Center (AGC) Geospatially Enabled Modeling and Simulation (GEMS) projects, and the DARPA Synthetic Environment for constructive simulation program. He was Principal Investigator and GIS Specialist for generating semantic terrain features for simulation behavior algorithms, using ArcInfo geospatial modeling capabilities, for US Army RDECOM, and managed VT MAK's Geospatial Research and Development group. Mr. Stanzione holds a Bachelor of Science and Master of Science in Photographic Science from the Rochester Institute of Technology.

Daniel Maxwell is President of KaDSci, LLC, a small decision sciences research company that provides services to multiple government agencies and commercial clients. Dan completed a full career in the US Army where he served as the Technical Director of the Joint Warfighting Simulation System (JWARS) Office in the Office of the Secretary of Defense (OSD). Dan served on the Defense Science Board Task Force on Intelligence, as well the Military Operations Research Society Board of Directors. He holds a Ph.D. in information technology from George Mason University, an MBA from Long Island University, and a B.S. from the Rochester Institute of Technology. Dan has research interests and has published in the areas of decision analytic modeling, simulation, resource allocation, and modeling and analysis for organizational leaders. Prior to forming KaDsci Dan led many research and analysis efforts as a corporate officer in a private research firms and in leadership roles for a Federally Funded Research Center.

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INTRODUCTION

The Simulation to Mission Command Interoperability Integrated Product Team (SIMCI OIPT) is an Army organization that is co-sponsored by the PEO for developing Simulations (PEO-STRI) and the PEO responsible for developing mission command systems (PEO-C3T). The SIMCI OIPT has a charter to develop solutions that live at the intersection of these two types of systems and their users. Almost three years ago SIMCI OIPT identified the generation, management and use of geospatial data as one of those vexing challenges that lives at the intersection of these two domains. Previous work has focused on increasing awareness in the community of the challenges and identifying cost-effective approaches to improving the state of the practice (Hieb & Maxwell, 2012). As part of the 2013 effort an analysis is underway of the current geospatial standards used in Modeling and Simulation (M&S) and how they compare to other current geospatial Industry standards. Research and analysis criteria include the amount of current use by Industry, the degree of openness of the standards, ability of the standards to satisfy the M&S requirements and the flexibility of the standards to adapt to changing technology. The results of this analysis are documented in this paper and support the increased use of open geospatial standards in the M&S community.

TERRAIN DATABASE GENERATION FOR SIMULATION

There are many strategies for developing a terrain database for simulation, and they all involve the same fundamental stages (Stanzione, 2012). Firstly, source geospatial data, which may come from US government organizations like the National Geospatial-Intelligence Agency (NGA), and the United States Geological Survey (USGS), or commercial companies, is acquired. As the accessibility of geospatial information has grown over the years, other markets that require similar types of data are producing it and are providing it on line. It is our estimation that there are literally petabytes of geospatial data available on the internet for practically any part of the world. The amount and accuracy of data is growing every day. One big reason this data has become so prevalent and useful is through the development and use of widely adopted geospatial data content and metadata standards, as we will discuss in this paper.

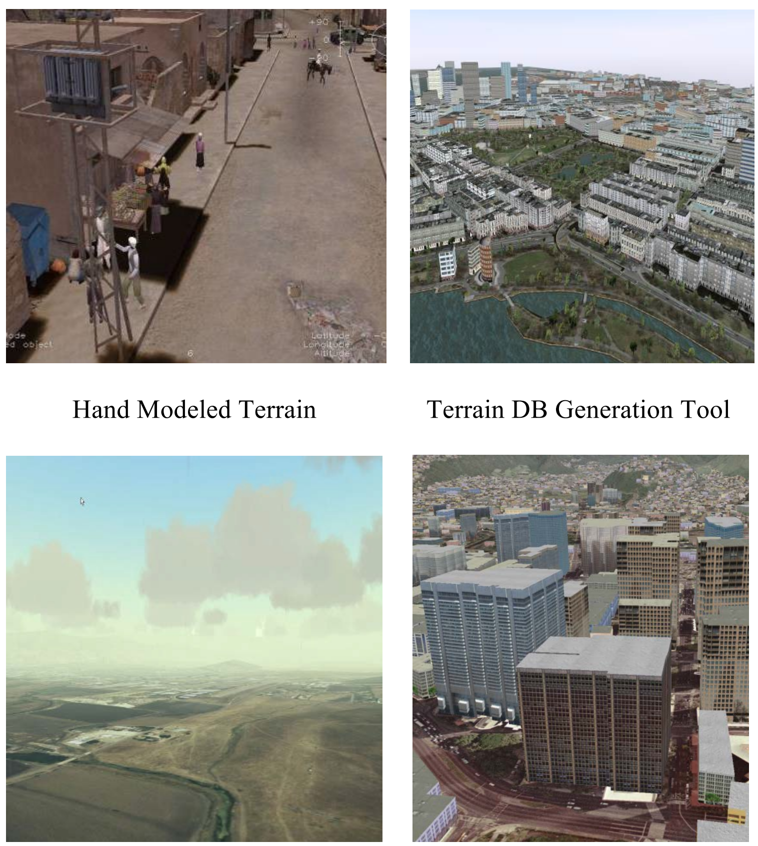
The second stage after acquiring the data is to refine it to meet the requirements of the intended simulation exercise or event. There are many tools available for refining the source data, from geographic information systems (GIS) to specialized simulation terrain database generation systems. Much of this work requires terrain professionals to ensure the different data sets are correlated and of the right fidelity for the simulation systems they will be used for. While specific tools have been developed for the simulation community, more general geospatial libraries have been developed that use open geospatial standards. These libraries can provide many capabilities that can be used to improve generation of simulation terrain databases.

The final stage is to construct the terrain databases to be used in the simulation applications. These can be two dimensional map-like terrains for Semi-Automated Forces (SAF) simulations, or three dimensional worlds for visualization and advanced terrain reasoning in live, virtual and constructive simulation applications. Some emerging database generation techniques can provide terrain data to a simulation "on the fly" using web streaming and procedural generation techniques, again taking advantage of open standards for geospatial data and services (Kuijper, 2011).

The current strategies for terrain database generation include hand modeling of the terrain, where tools such as Autodesk's 3DS Max or Presagis' Creator are used to build 3D models of the terrain and its contents. These hand modeled terrains are typically high quality and very realistic, but are also very expensive to produce. Another strategy is to use database generation tools, such as TerraSim's TerraTools, TrianGraphics' Trian3D Builder, and Presagis' TerraVista, to automate some of the process. For instance, parametric algorithms can generate large areas of dense geotypical detail, or automatically cut and fill roads into hillsides. The quality and detail of the terrain databases can be quite high, but they are defined by the terrain tool's capabilities and the design choices made by expert users of the terrain tools. For many simulation applications these terrain databases are required because they cannot use source data directly as a runtime format or need additional detail to be added to the terrain to satisfy training or other requirements.

The use of open geospatial standards allows other terrain database generation strategies, such as "Direct from Source", where layered source data in standard formats can be ingested directly into the simulation applications and either rapidly processed into a simulation compatible terrain database or used "as is" at runtime. This can be a very rapid process and can allow simulation to be performed on new geographic areas very quickly. It is also very dynamic as new or updated source data can be quickly loaded to augment existing source data that is already in use. It can be scalable for large areas, and less expensive than previously discussed methods, as no off-line processing or tools are required. This can save thousands of dollars and tens to hundreds of labor hours over the other methods for every database. It can also lead to performance issues, though, as this data is not optimized for runtime applications, and it is limited by the quality of the source data if the data refining process is not performed on the input data. Each application may internally process the source data differently, leading to correlation issues, but the use of consistent tools that process these open data formats can help standardize these on line processes. A special case of direct from source is the Geospatially Enabled Modeling and Simulation (GEMS) concept developed by VT MAK and ESRI for the US Army Geospatial Center (Lashlee & Stanzione, 2008).

Another terrain database generation strategy made possible by open standards is the use of streaming geospatial data from servers (Wiesner et al., 2011). This strategy can use GIS Servers or web-mapping services to provide world-wide geospatial data at various quality and resolution levels. These servers can be on local networks or on the Internet, and examples include Microsoft Virtual Earth, ESRI's ArcGIS Online and ArcGIS Server/Data Appliance, OpenStreetMap, and many others. These servers typically support open standard protocols, such as the Web Map Service (WMS) and Web Feature Service (WFS) from the Open Geospatial Consortium (OGC). Commercial terrain database servers from VT MAK and Presagis have become available in the last few years that provide these services directly for simulation applications. Figure 1 shows the typical types of terrain databases that these approaches can produce.



Hand Modeled Terrain — Terrain DB Generation Tool

Direct From Source — Streaming Terrain

Figure 1. Terrain Databases from Different Approaches

GEOSPATIAL STANDARDS

Geospatial standards typically fall into one of three categories – 1) *Data Content Standards, 2) Metadata Standards, and 3) Geospatial Services Standards*. *Data Content Standards* define the data content for geospatial features, images, elevation surfaces, and collections of these data as datasets. Examples of geospatial data content standards include the Geography Markup Language (GML), Digital Terrain Elevation Data (DTED), and JPEG. *Metadata Standards* are used to establish the semantics of data, to ensure the data is used correctly. Attributes of the data are provided that help achieve a common understanding of the meaning of the data (Richbourg, 2012). Geospatial metadata standards support improved data discovery and sharing within the geospatial community. Examples of geospatial metadata standards include the ISO 19115:2003 Geographic information -- Metadata standard, the National System for Geospatial Intelligence Metadata Foundation (NMF), an implementation profile of the ISO 19115 standard and the DoD Discovery Metadata Specification (DDMS), and the Content Standard for Digital Geospatial Metadata maintained by the Federal Geographic Data Committee (FGDC).

Geospatial Services Standards define the network protocols that can be used to discover geospatial data sites and obtain geospatial data from those sites automatically. These sites are typically publically available and standardized for use by all programmers. Examples of geospatial services standards include the Web Map Service (WMS) and the Web Feature Service (WFS) from the OGC.

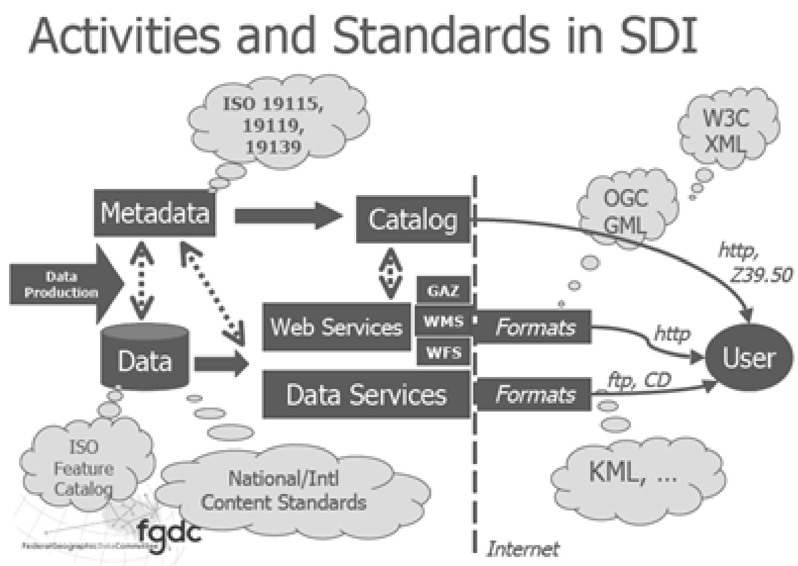


Figure 2. Relationship Between Geospatial Activities and Standards (FGDC, 2009)

Figure 2 is a diagram from the FGDC, an interagency committee that promotes the coordinated development, use, sharing, and dissemination of geospatial data on a national basis that shows the relationship between data, metadata, and web services. This nationwide data publishing effort by the FGDC is known as the National Spatial Data Infrastructure (NSDI), which is a framework of geographic data, metadata, and tools that are interactively connected through standards in order to improve the use of spatial data (OMB, 2002). The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, the Interior, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; and the Tennessee Valley Authority.

There are many open geospatial standards that are used in the M&S terrain database generation process, such as SEDRIS, and there are others that may be used in the future. The term “open standard” is not precisely defined and is open to interpretation. Different definitions may emphasize different aspects of openness, such as the standard specification, the drafting process to create and maintain the standard, the ownership of the resulting standard, or the cost to obtain or use the standard. Many specifications that are sometimes referred to as standards or defacto standards are usually proprietary and only available under restrictive terms from an organization that developed and owns the specification. The OpenFlight format is a good example of this, and while these specifications are not considered to be fully open, they have become open enough to be adopted and accepted in the community.

The OGC (OGC, 2013) develops specifications that enable interoperability between different products that consume geospatial data, whether proprietary or open source. This organization defines Open Standards as standards that are:

1. Freely and publicly available – They are available free of charge and unencumbered by patents and other intellectual property.
2. Non discriminatory – They are available to anyone, any organization, anytime, anywhere with no restrictions.
3. No license fees - There are no charges at any time for their use.

4. Vendor neutral - They are vendor neutral in terms of their content and implementation concept and do not favor any vendor over another.
5. Data neutral – The standards are independent of any data storage model or format.
6. Defined, documented, and approved by a formal, member driven consensus process. The consensus group remains in charge of changes and no single entity controls the standard.

There are a number of organizations that are developing open geospatial standards, in addition to OGC, the International Standards Organization (ISO) Technical Committee 211 for geographic information and geomatics, the ISO/IEC Joint Technical Committee 1/SC 24 for computer graphics, image processing and environmental data representation, and the European Committee for Standardization (CEN) generate geospatial standards. Similar organizations are developing open source geospatial tools, with the most prominent being the Open Source Geospatial Foundation (OSGeo). While there is a natural partnership between open standards and open source software organizations, the differences in their missions must be clear. Open standards organizations are developing standards to promote software interoperability, while the open source organizations exist to promote and enable the development of software that is freely available at no or little cost to users and make the source code available for further development by others. Open source software development projects can take advantage of open standards, but proprietary software can and is also developed based on open standards.

There are degrees to how products adhere to standards that must be considered. For instance, the OGC has a formal Compliance Testing Program that provides a formal process for testing product compliance against all mandatory elements of the implementation of their standards in that product. If a product passes this test, it is said to be an OGC Compliant product. OGC does not charge a fee for compliance testing under the testing procedure, but does charge a Trademark Licensing Fee to organizations that want to claim compliance with the OGC standards. The cost of the initial licensing fee and the annual renewal fee depends on the total gross annual revenue of the licensee and the type of membership the licensee has with the OGC. These fees range from $80 to $7000 annually per product, with a maximum limit per company. A product that implements an OGC standard but has not gone through the formal testing process is said to “implement the OGC standard”.

GEOSPATIAL STANDARDS USED IN M&S

There is a wide variety of open and not so open geospatial database, interchange, and source data specifications and standards used in the modeling and simulation community, particularly for terrain database generation. Some of the more widely known include the Common Data Base (CDB), SEDRIS, and NGA content specifications.

The Common Data Base (CDB) (CDB, 2012) is a specification that has been developed by CAE and its modeling and simulation product subsidiary Presagis for the US Government. CDB is used to help standardize the data and processes used to generate terrain databases for US SOCOM simulation systems. The CBD specification utilizes five industry formats for representing different data types – TIFF, OpenFlight, RGB, Shapefiles, and JPEG 2000. The Tagged Image File Format (TIFF), along with the GeoTIFF variant, is used for the representation of terrain elevation and surface characteristics. Presagis’ OpenFlight format is used for the representation of 3D cultural features and moving models, and a simple RGB format is used for textures associated with those 3D features and models. ESRI Shapefiles are used to representing point, lineal and areal 2D/3D culture features, and JPEG 2000 is used for a representation of compressed terrain raster imagery.

SEDRIS (SEDRIS, 2013) is a family of open standards that were developed to promote the reuse of terrain data between terrain database producers, reducing the time and cost to build terrain databases by being able to share processed geospatial data used to produce the final runtime terrain

Table 1. SEDRIS ISO Standards

ISO/IEC 18023-1	SEDRIS -- Part 1: Functional specification
ISO/IEC 18023-2	SEDRIS -- Part 2: Abstract transmittal format
ISO/IEC 18023-3	SEDRIS -- Part 3: Transmittal format binary encoding
ISO/IEC 18024-4	SEDRIS language bindings -- Part 4
ISO/IEC 18025	Environmental Data Coding Specification (EDCS)
ISO/IEC 18026	Spatial Reference Model (SRM)
ISO/IEC 18041-4	EDCS language bindings -- Part 4
ISO/IEC 18042-4	SRM language bindings -- Part 4

databases required for different simulation applications and vendor specific formats. SEDRIS meets the definition of an Open Standard as defined by OGC above. SEDRIS provides a data representation and interchange specification for allowing different terrain database vendors to share source and processed geospatial data used to generate different terrain database formats for the same part of the world. As part of the development of this format, a data representation model (DRM), spatial reference model (SRM) and environmental data coding specification (EDCS) were developed, which have all been standardized. The SEDRIS standards, which are all data format standards, were developed cooperatively between ISO and the International Electro-Technical Committee (IEC), and include the standards shown in Table 1.

The National Geospatial-Intelligence Agency (NGA) has developed many standards for geospatial data content which have been used for terrain database generation. Some of the more common data formats include the Digital Terrain Elevation Data (DTED) for raster elevation data, Digital Feature Analysis Data (DFAD) for feature data and attributes, and the Compressed ARC Digitized Raster Graphics (CADRG) for raster map data. The NSG Feature Data Dictionary (NFDD), which is a profile of the DGIWG Feature Data Dictionary (DFDD), has replaced the DGIWG Feature and Attribute Coding Catalogue (FACC), a feature coding model that has been used in many simulation applications, although many are now using the SEDRIS EDCS standard. An emerging group of standards that may be used in M&S in the future are the Motion Imagery Standards Board (MISB) standards for full motion video. These are used in the autonomous vehicle sensor imagery world and can be used for simulated full motion imagery as well.

The Simulation Interoperability Standards Organization (SISO) has always been involved in the geospatial standards area, and many standards, including SEDRIS, have been developed to some extent through this organization. Specifically, both the EDCS and DRM were developed in their respective SIW Product Development Groups (PDG). Recent work includes a Study Group on the Reuse and Interoperation of Environmental Data and Processes (RIEDP) which has produced a final report in 2012 (SISO, 2012). Subsequently, a PDG was formed and two products were nominated: the Environmental Data Model Foundations, as a a SISO Guidance document, and the Environmental Detailed Features Description, as a SISO Standard. The Environmental Data Model Foundations document is composed of the Reference Process Model (RPM) and the Reference Abstract Data Model (RADM, which can be used by terrain database generation projects to compare, contrast, and map their data generation process and data model capabilities to these models. The Environmental Detailed Features Description standard is another environmental feature and attribute coding specification, which will include standardized dictionaries and associated metadata.

OGC GEOSPATIAL STANDARDS

Besides the open geospatial standards that are already being used in the M&S community, there are other open standards that may have utility for generating terrain databases. Within the various definitions of open geospatial standards, there are quite a number that fit within the degrees of openness. These include the data content standards, metadata standards, and web service standards, as we have mentioned previously. Tables 2 through 4 provide a summary of some of these other open standards that may have the most usefulness for modeling and simulation. We provide a short description of these standards in the tables along with their current or potential use in the modeling and simulation terrain data base generation process. Appendix A has the web sites that these standards can be obtained from. The data format standards represent multiple geospatial data formats that are somewhat overlapping but provide unique solutions for some data. The open standards for metadata (Tables 3 & 4) provide both formats for representing data about the geospatial data, but also serve to access and discover geospatial data sets.

The open standards for geospatial services (Table 5) define web based services for discovering, viewing, downloading, and transforming geospatial data (Kralidis, 2007). Discovery services search for geospatial data sets and geospatial data services using corresponding metadata, and may display the metadata content. View services may provide display, navigation, zooming and panning, or overlay functions, at a minimum, while download services enable portions of or complete spatial data sets to be downloaded. Transformation services enable spatial data sets to be manipulated at the source before transmittal.

Table 2. OGC Standards for Data Formats

Standard	Description	Current or Potential Use
OGC Geography Markup Language (GML) Encoding Standard (ISO 19136)	An XML grammar for expressing geographical features.	A standard format for all geographical feature data
OGC Keyhole Markup Language (KML)	An XML grammar for expressing two dimensional map and three dimensional Earth views.	Importing Goggle Earth data into the Terrain Database (TDB) Generation process
ISO Simple Features	A format for point, line, polygon, and multi-point feature data.	Importing GML feature data sets
OGC City Geography Markup Language (CityGML) Encoding Standard	An information model for the representation of 3D urban objects that can be shared across different applications. CityGML is based on a number of standards from OGC, ISO 191xx family, the W3C Consortium, the Web 3D Consortium and OASIS.	Importing urban feature data

Table 3. OGC Standards for Metadata

Standard	Description	Current or Potential Use
OGC Web Coverage Service (WCS)	Defines a standard interface and operations that enables interoperable access to geospatial "coverages", which include satellite images, digital aerial photos, digital elevation data, and other phenomena represented by values at each measurement point. WCS provides available data together with detailed descriptions, syntax and semantics to allow the data to be processed rather just portrayed.	Can be used to provide semantic information along with geometric information
OGC Catalogue Service – Web (CSW) Interface Standard	Supports the ability to publish and search collections of metadata for data, services and related information objects.	M&S applications can use catalogues to query and evaluate potential data sets

Many of the standards and specification described in the above tables are implemented in available libraries, making it easier to implement these standards in applications. One particularly useful library, which implements many of the open geospatial standards, is the Geospatial Data Abstraction Library (GDAL) from the Open Source Geospatial Foundation. It was originally developed for raster geospatial data formats, and as such it supports a long list of raster formats, including JPEG 2000, DTED, TIFF, and GeoTIFF. Among the open standards referenced above, it supports KML, OGC WCS, and OGC WMS raster formats and services. For feature data, GDAL includes the OGR Simple Features Library to access a variety of vector file formats including ESRI Shapefiles. GDAL is available in C and C++, and bindings are available for Perl, Python, Java, and C#. GDAL is released under the permissive X/MIT style free software license, which permits reuse within proprietary software provided all copies of the licensed software include a copy of the MIT License terms. The use of open source libraries like GDAL can help promote standardization of tools and process across M&S organizations.

Table 4. Other Open Standards for Metadata

Standard	Description	Current or Potential Use
Geographic Information – Metadata (ISO 19115/19139)	ISO 19115 defines the schema required for describing geographic information and services, including information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data. ISO 19139 is an XML implementation of the schema.	A schema that can be used to standardize metadata throughout the M&S TDB Generation process
FGDC Content Standard for Digital Geospatial Metadata (CSDGM), (ISO 15836)	Provides a common set of terminology and definitions for the documentation of digital geospatial data. The standard establishes the names of data elements and compound elements (groups of data elements) to be used for these purposes, the definitions of these compound elements and data elements, and information about the values that are to be provided for the data elements.	A common vocabulary that can be utilized in the M&S TDB Gen process

Table 5. OGC for Geospatial Services

Standard	Description	Current or Potential Use
OGC Web Map Service (WMS) Interface Standard, (ISO 19128)	Services that present location information in a raster format	Can be used for streaming imagery data, elevation data, and map data
OGC Web Map Tile Service (WMTS) Interface Standard OSGeo Tile Map Service (TMS) Specification	Services that present location information in a raster format using tiles of predefined content, extent, and resolution. WMTS was derived from the Open Source Geospatial Foundation (OSGeo) Tile Map Service Specification.	A more scalable service for access geospatial data in real time for streaming data to M&S applications
OGC Web Processing Service (WPS) Interface Standard	Defines a standardized interface for publishing of geospatial processes, and the discovery of and binding to those processes by clients.	Can be used to perform GIS type functions remotely on data sets before downloading or during runtime
OGC Web Feature Service (WFS) Interface Standard	Defines services to access specific feature data from a larger feature data set.	Access of feature data for streaming applications

BENEFITS OF OPEN GEOSPATIAL STANDARDS

There are many benefits to using open standard based geospatial data and services over proprietary data formats and tools. Open standards promote interoperability of data and processes across multiple organizations, making it easier to share data. This avoids the stovepipe nature that currently exists in simulation terrain database generation, where the same areas of the world have been modeled multiple times by different organizations. Sharing the data of these areas as well as the tools to process that data in similar ways will help ensure that operations such as cleaning and correlating multiple data sources in done once and the results shared in consistent ways. SEDRIS was developed partly to share terrain and 3D model data for the Army's Close Combat Tactical Trainer (CCTT) program to avoid duplication of effort in building terrain database for training, and the Army's Synthetic Environment CORE (SE CORE) programs is using tools that are open standard compliant to clean and correlate geospatial data for multiple simulation system clients. Because organizations can now store data in standard formats and share them with other organizations, the amount of geospatial data available has grown exponentially in the last decade. For instance, high fidelity, geospecific building information is now available for most major US cities, and other cities around the world. Even small town governments now employ GIS specialists to capture, maintain and distribute geospatial data.

Utilizing the new OGC standards-based geospatial data available on-line speeds up the terrain database generation process. Previously, geospatial data had to be ordered from organizations like NGA or obtained ahead of time in anticipation of generating a terrain. This made it more difficult to generate a terrain database quickly or update an existing database with the latest information. With so much on line data, new data can be obtained quickly, and if tagged with relevant metadata, the quality and pedigree of that data can be determined as well. ESRI's ArcGIS Online site, for instance, provides both free and subscription services for accessing and sharing worldwide geospatial data, including world imagery map services that can provide one meter or better satellite and aerial imagery in many parts of the world, and 15 meter imagery for the rest of the world.

Having standards based geospatial data available on line also now makes it possible to stream data directly to M&S applications over a network using data content and web services standards, as well find new sources of data that may have gone unnoticed before. Organizations that generate terrain databases have options about much data can or should) be stored locally or downloaded as needed, depending on the mission of the M&S application(s) that use that data. For instance, an organization that performs mostly training can build large static terrain databases and store them locally, if the training is standardized for multiple groups over time. On the other hand, organizations that want to perform mission rehearsal on the most up to date geospatial data may elect to have a more dynamic approach, downloading data and performing rapid terrain database generation or streaming that data directly into their M&S applications. In some cases, there could be a hybrid approach, with large databases built and stored locally and changes downloaded as needed to update the foundation database. Standardized formats, with well supported metadata, tools, and web services, are the foundation for allowing these different approaches.

Geospatial software vendors understand the value of supporting open standards and opening up proprietary formats. ESRI, the largest GIS company in the world, has embraced the OGC standards and have compliance tested most of their products. M&S software companies also beginning to embrace this openness. Presagis has opened up the OpenFlight proprietary format by offering a free API to read, write, and extend OpenFlight terrain. Their TerraVista terrain database generation and Creator 3D modeling tools support open standards, and their SEGen Server product performs procedural modeling in real time using the CDB specification databases. VT MAK now offers a Terrain Server product that is based on WMS and WFS web services. The Federal Aviation Administration is using the Terrain Server to provide a worldwide terrain database in their NextGen Integration and Evaluation Capability (NIEC) Laboratory.

We provide here an example of how open geospatial data and services can be used in support of simulation applications. Imagine a training requirement for a specific area of the world, for example Boston, Massachusetts. Geospatial discovery services can be used to locate servers that provide geospatial data that may be used to generate the required terrain representation. For Boston, there is the City of Boston GIS Data Hub that hosts a wide range of city GIS data including roads and building footprints. Elevation and imagery can be obtained from the ESRI ArgGIS Online site. The metadata associated with those data can be used to further qualify those data for use in the specific application. If the data are determined to be useful, direct download of GIS data files or WMS and WFS web services can then be used to make requests for the specific area to be modeled, and receive the data based on those requests. This data can then be processed into a terrain database using traditional methods or used in a "direct from source" fashion as the runtime terrain format, depending on how quickly the training needs to be performed, among other technical factors such as the quality of the data and the extent of the area. An initial terrain representation containing elevation and draped imagery may be obtained and used for initial training, with more detailed feature data added at a later time, allowing training to take place while the final terrain database is being processed. The flexibility offered by these standards and processes can be used in this way to improve force readiness.

CONCLUSIONS

Open Standards, Web Services, and Geospecific Metadata are changing the paradigm of terrain databases for M&S and C2 applications. Petabytes of geospatial data that can be streamed from web sites around the globe are now available for use in the terrain database generation process. While C2 systems have been able to leverage industry standards and applications and are moving towards open standards, particularly through the use of OGC standards compliant software such as the Commercial Joint Mapping Toolkit (CJMTK), the M&S community has been slower to embrace these new methods of obtaining and utilizing geospatial data. We are now seeing the use of open standards and services starting to emerge in the M&S community, with new products and processes that are shrinking the time and cost to develop terrain databases, while at the same time providing more up to date, dynamic , and realistic visual and other terrain representations. As the use of open standards and tools increases, we should see a vast improvement in the terrain database generation process and resultant terrain databases, as well as improved training and readiness of our warfighters, due to the timeliness and accuracy of the terrain representations.

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APPENDIX A - REFERENCES TO OPEN STANDARDS

Standard	Title	Web Site
SEDRIS (ISO/IEC 180XX) *See Table 1*	SEDRIS Technologies	http://www.sedris.org/
GML (ISO 19136)	OGC Geography Markup Language Encoding Standard	http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32554
KML	OGC Keyhole Markup Language	http://www.opengeospatial.org/standards/kml/
ISO 19125 ISO/IEC 13249-3	ISO Simple Features	http://www.iso.org/iso/catalogue_detail.htm?csnumber=40114
CityGML	OGC City Geography Markup Language Encoding Standard	http://www.opengeospatial.org/standards/citygml
WCS	OGC Web Coverage Service	http://www.opengeospatial.org/standards/wcs
CSW	OGC Catalogue Service – Web Interface Standard	http://www.opengeospatial.org/standards/cat
ISO 19115/19139	Geographic Information – Metadata & XML Schema	http://www.iso.org/iso/catalogue_detail.htm?csnumber=26020 http://www.iso.org/iso/catalogue_detail.htm?csnumber=32557
CSDGM (ISO 15836)	FGDC Content Standard for Digital Geospatial Metadata	http://www.fgdc.gov/metadata/csdgm/
WMS (ISO 19128)	OGC Web Map Service Interface Standard	http://www.iso.org/iso/catalogue_detail.htm?csnumber=32546
WMTS	OGC Web Map Tile Service Interface Standard	http://www.opengeospatial.org/standards/wmts
TMS	OSGeo Tile Map Service Specification	http://wiki.osgeo.org/wiki/Tile_Map_Service_Specification
WPS	OGC Web Processing Service Interface Standard	http://www.opengeospatial.org/standards/wps
WFS	OGC Web Feature Service Interface Standard	http://www.opengeospatial.org/standards/wfs