# NGA's Approach to Address M&S Interoperability

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## ABSTRACT

Throughout the years, the Modeling and Simulation (M&S) industry has sought solutions for interoperable training and mission rehearsal events. These kinds of events tend to leverage commercially available and/or proprietary software to consume Geospatial Intelligence (GEOINT) content to produce event content, which may or may not be accurate or geospecific in nature. Each vendor, Service, Command, program, or association participating in these events often have a set of preferred formats, data sources and ambiguous fidelity definitions. The lack of common data, definitions and processes present correlation and accuracy challenges that could potentially risk fair fight scenarios in these types of events, which represent real world environments and challenges.

The Department of Defense (DoD) issued a memorandum via the Senior Steering Group (SSG) for the Under Secretary of Defense (USD) calling for a national level archive of simulation ready content to address simulator interoperability between the DoD and Intelligence Community (IC). As part of this memo's directives, the National Geospatial-Intelligence Agency (NGA) addresses simulator interoperability by standing up a capability known as Foundation GEOINT in 3-Dimensions (FG3D). The FG3D mission ensures geospatial data interoperability by making authoritative M&S content accessible on all U.S. Government networks. The initial authoritative data holdings are comprised of a combination of United States Special Operations Command (USSOCOM) and Joint Staff J7 content as well as the FG3D tools, which can produce Common Database (CDB) content and translate such content to users. The generation of additional authoritative content occurs on demand, leveraging available assets within the NGA Open Data Store (ODS).

## ABOUT THE AUTHORS

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## INTRODUCTION

The Department of Defense (DoD) issued a memorandum via the Senior Steering Group (SSG) for the Under Secretary of Defense (USD) calling for a national level archive of simulation ready content to address simulator interoperability between the DoD and Intelligence Community (IC) communities. As part of this memo's directives, the National Geospatial-Intelligence Agency (NGA) is to address simulator interoperability by standing up a capability known as the Foundation Geospatial Intelligence (GEOINT) in 3-Dimensions (FG3D). Throughout the years, the Modeling and Simulation (M&S) industry has sought solutions for interoperable training and mission rehearsal geospatial data. The FG3D mission is to ensure geospatial data interoperability by making authoritative M&S content accessible on all U.S. Government networks.

## BACKGROUND

Freeman et al (2018) described M&S challenges in an Open Geospatial Consortium (OGC) White Paper. The paper described the issues on why creating modern geospatial standards has proven to be a challenge for the M&S industry. Multiple standards have promised to be a panacea for all; but few, if any, standards have delivered on their promises. Difficulties facing geospatial terrain standards have included proprietary formats, proprietary tools, rarely used data containers, obsolescence and disconnected data silos.

The community needs authoritative data to support various mission use cases. However, the DoD guidance on authoritative data is: "A source of data or information that is recognized by members of a Community of Interest (COI) to be valid or trusted because it is considered to be highly reliable or accurate or is from an official publication or reference (e.g., the United States (U.S.) Postal Service is the official source of U.S. mailing ZIP codes) (DoD 8320.2)." This guidance is ambiguous as it does not cover factors like collection date, quality assurance and general mechanisms to encode the factors as metadata.

A lack of authoritative data is a major issue with standards. Several factors contribute to making data authoritative including: why the data was collected, usage, correctness, accessibility, availability, freshness, lifecycle management processes and known quality assurance and control. Authoritative data must include metadata that describes all of these aforementioned factors and more. To ensure confidence in the data, the input metadata must be known to assess its mission support. Otherwise, the data will be placed in a situational awareness category with a lower confidence, which restricts its ability to support the modeling and simulation community. NGA has strict standards in assessing GEOINT data to ensure it is photogrammetrically sound and meets statistical thresholds aligned to specific mission support. Only after tedious assessments can the source data be given a confidence rating and deemed authoritative.

Accessibility of data on all the DoD networks is another significant issue with standards. Within M&S, most data efforts are done on the unclassified side while high quality data sources available from NGA are often in the classified domain. This presents a challenge to the M&S community because the lack of unclassified data drives decisions to leverage non-authoritative data sources or dated source products. The M&S community often uses sources like OpenStreetMaps, where data is accessible to anyone on the planet, with no guarantees of accuracy or fidelity. While in certain circumstances data sources like OpenStreetMaps are suitable, in the use case of high precision data needs like targeting and mensuration, OpenStreetMaps presents a major risk to the operational use.

Another issue with geospatial M&S standards is the lack of freely available tools to build data. Standards are often created independent of tools. While creating a standard independent of tools is inherently not an issue, capability gaps are often addressed by tools that may be proprietary. Beyond tools being proprietary, tools often fail to keep tempo

with changing standards. In high technology areas, standards change sometimes at a pace that supersedes industry's ability to maintain compliance within their tool sets.

Another significant issue with standards is the blending of training and operational data. The M&S community's reach is quickly growing beyond training to operational use cases. As training and operational use cases of data needs blur, the demand for authoritative data increases to ensure no malicious content or errant data reaches its way to operational applications. Similarly, the use of geotypical or procedurally generated content in training datasets presents another operational data risk. The core challenges of data in the 21st century are "Can the data be trusted?" and "Can I get it when I need it?"

## LESSONS LEARNED FROM M&S EFFORTS FOR INTEROPERABILITY

### Synthetic Environment Data Representation and Interchange Specification (SEDRIS)

SEDRIS was initiated in 1994 as a co-sponsored activity by the Program Manager for Combined Arms Tactical Trainer (PM-CATT) at the Simulation Training and Instrumentation Command (STRICOM, now PEO STRI) and the Synthetic Theater of War (STOW) program at the Defense Advanced Research Projects Agency (DARPA). The objective was to provide solutions to the complex problem of environmental data representation and interchange for networked heterogeneous applications. The SEDRIS architecture centered on the creation of DoD unique data representation models, environmental coding specifications, spatial reference models, file formats, and APIs. The DoD led the development of SEDRIS with representation from industry. From the inception of SEDRIS to its final software release in July 2011, the majority of funding for SEDRIS originated from the DoD. SEDRIS utilization for terrain distribution significantly decreased and ultimately ended when DoD resources diminished.

The SEDRIS initiative has both positive and negative lessons learned to help steer future M&S initiatives. A strength of SEDRIS is well-developed documentation describing the various data models in use and a level of sufficiency in open source software to read and write the terrain. An area affecting the potential success with the SEDRIS initiative was its reliance on DoD unique formats with no commercial adoption.

### Naval Air Systems Command (NAVAIR) Portable Source Initiative (NPSI)

NPSI is a concept with a simple goal to minimize the redundancy in database production across platforms without inhibiting innovation. The basic concept of NPSI is to capture value added work performed on raw source data. This concept has resulted in cost savings and increased efficiency of database production to many DoD programs by minimizing the purchasing and processing of new source data required for future developments. The NPSI archive stores refined source data in datasets and makes the datasets available for utilization by future programs. However, unlike the refined source data, run-time databases are not stored in the archive.

A strength of the NPSI is the utilization of widely used commercial data formats to simplify the reading and distribution of NPSI data. An area for improvement with the NPSI initiative is its weak and unenforced conceptual data model that hinders and complicates data reuse while not providing robust metadata.

### Synthetic Environment Core (SE CORE) Master Database (MDB)

The SECore MDB is a folder and file-based repository of geospatial data representing all of the geographical areas that the SE Core program has collected, prepared and delivered to the U.S. Army. The SE Core MDB is defined for use within the SE Core production process and is designed to support the production of the runtime formats required for each U.S. Army Integrated Training Environment (ITE) systems.

The MDB elevation data is contained in GeoTIFF and exportable in Digital Terrain Elevation Data (DTED) formats. The feature data is stored in Esri Spatial Database Engine™ (SDE) and exportable to Esri Shapefile and file geodatabase formats, and now OGC GeoPackage. The Data Model is unique to SE Core and leverages the SEDRIS Environmental Data Coding Specification (EDCS) data dictionary. The MDB imagery is stored in GeoTIFF and exportable to TIFF and JPEG2000. The MDB 3D models are stored in both OpenFlight® (Presagis) and FilmBox™ (AutoDesk) for virtual and gaming, respectively. The 3D models, textures and material maps are stored in Photoshop Document (PSD) files and exported to the Truevision Graphics Adapter (TGA) for processing to runtime formats. All

metadata is stored in XML. The SE Core MDB contains only full government purpose rights data and is distribution controlled by PEO-STRI.

The SE Core MDB is not a sharing standard. It is a content data store, defined in industry formats, and used internally in the production of the U.S. Army ITE simulation system runtime formats. Long term, the goal of SE Core was to align the U.S. Army M&S Geospatial Data standards with Operational Mission Command (MC) geospatial data standards; however, the U.S. Army has moved its major investments to One World Terrain (OWT).

The MDB strength is in the initiative of commercial file standards as the means for terrain data storage and well defined use case models. Improvements of the MDB initiative include using the NGA logical data model in lieu of M&S unique logical data models (i.e. EDCS) and employing a conceptual model that supports data sharing. At the time of this writing, the MDB program is being decommissioned and all efforts will be aligned to support the U.S. Army OWT.

**One World Terrain**

At the time of this writing, One World Terrain is in active development and the reader should take caution in the descriptions of OWT in this paper.

OWT is the latest effort from the U.S. Army to meet its enterprise need for M&S data across its complex and changing ecosystem. OWT defines stratums of data: Base Globe, 3D Foundation and 3D Insets. The Base Globe provides worldwide coverage of data at lower resolutions (i.e. 15m imagery, 30m elevation, 30m land use) where the intent is to provide context for Area of Interest (AOI) selection based on procedurally generated content. The 3D Foundation dataset is a 3m SE90 error dataset of photogrammetry based on 3D point clouds calculated from Maxar's fortuitous stereo satellite imagery with a resolution of 50cm imagery, 50cm elevation and 3D objects in various forms. The 3D Insets provide high resolution content suitable for dismounted soldier-based training. The 3D Insets are geo-registered to the 3D Foundation datasets.

All of the OWT datasets are stored in the OGC Community Standard for 3D Tiles based on the Khronos standard for glTF. From the OGC web page for 3D Tiles: "3D Tiles is designed for streaming and rendering massive 3D geospatial content such as Photogrammetry, 3D Buildings, BIM/CAD, Instanced Features and Point Clouds. It defines a hierarchical data structure and a set of tile formats which deliver render capable content. 3D Tiles does not define explicit rules for visualization of the content; a client may visualize 3D Tiles data however it sees fit." OWT has built custom extensions to 3D Tiles to include metadata and vector information and defines this as its Well Formed Format (WFF).

It is premature to define lessons learned based on OWT WFF. The benefits of OWT at this juncture of time center on leveraging OGC Standards with extensions and photorealistic 3D content. Potential challenges to be answered over time by OWT include the use of proprietary tools and support of constructive simulation.

**Common DataBase (CDB)**

CDB is an open standard defining physical, logical and conceptual models for a single "versionable" virtual representation of the earth. A CDB structured data store provides for a geospatial content and model definition repository that is plug-and-play interoperable between database authoring workstations. Moreover, a CDB structured data store can be used as a common online (or runtime) repository from which various simulator client-devices can simultaneously retrieve and modify, in real-time, relevant information to perform their respective runtime simulation tasks (OGC CDB Standard, 2021).

CDB was developed by United States Special Operations Command (USSOCOM) to meet the need for a rapid, large-scale production capability for worldwide simulation databases for the 160th Special Operations Aviation Regiment and other Special Operation Forces (SOF) simulations. The key design goals of CDB were to: assure correlation between simulation subsystems by eliminating alternate storage formats of the same terrain, meet the ability to rapidly generate databases for mission rehearsal timelines, reduce the size of databases stored in a facility by eliminating the need of replication for each individual simulation subsystem and simplify configuration by eliminating multiple representations of the same terrain (Freeman 2017).

Beyond the key design goals of CDB, core ideas of CDB consist of: organizing GIS data in a standardized and documented structured data repository to promote data reusability and interoperability amongst systems and vendors, prebuilt Levels of Detail (LOD) to enable the same correlated terrain data to be used by numerous simulation systems, even though they may be operating at different altitudes and distances from the ground, and the ability to dynamically update the terrain during a simulation exercise and share the resultant terrain in near real time across all of the simulation clients participating within the exercise.

To help steer future M&S initiatives, the CDB leverages commercial file standards as the means for data storage, well-defined conceptual models and an ability to serve as both a source repository and runtime format. Improvements to the CDB initiative include reducing the complex and voluminous file and folder system on disk.

## SENIOR STEERING GROUP MEMO

In late 2018, the USD convened the SSG to address USSOCOM challenges of interoperability. The USD composed a memorandum titled "Simulator Interoperability Issues." USSOCOM lacked an effective mechanism to share data across the DoD for training and mission rehearsal events within their simulation ecosystem. The SSG concluded the root causes challenging USSOCOM centered on geospatial data, cybersecurity and policy. The SSG recommended a phased plan to address these root causes of interoperability challenges.

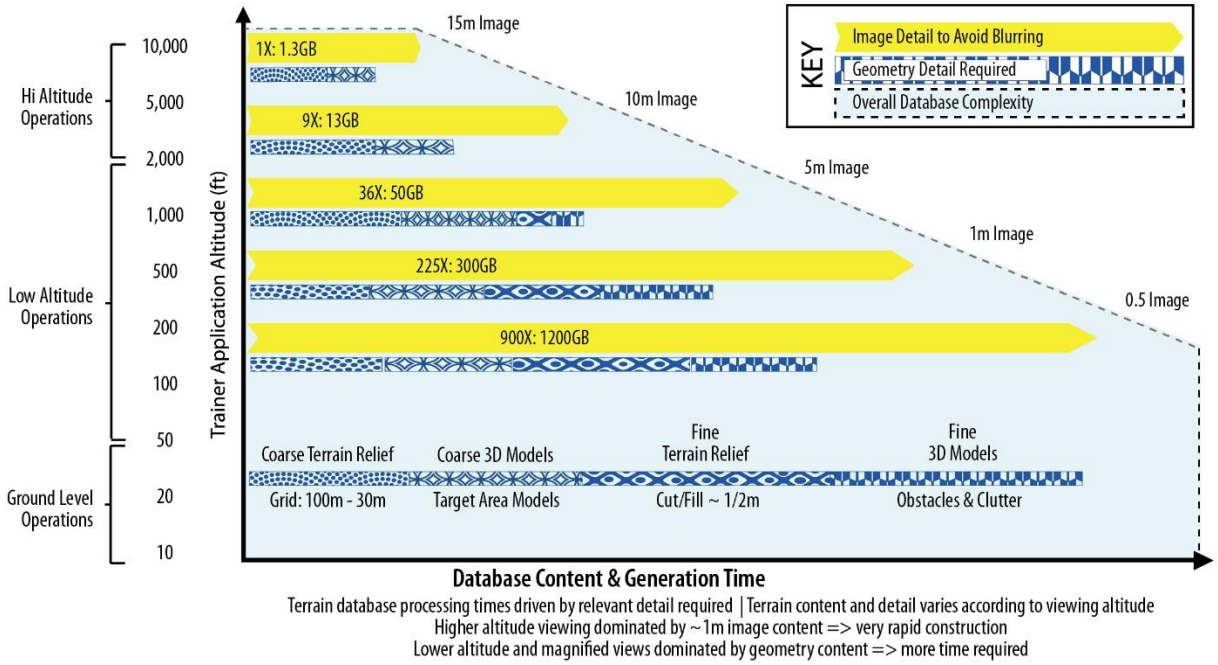


**Figure 1: Data Content & Generation Times**

The challenges of geospatial data for the M&S industry stem from the lack of correlation, timeliness and inadequate fidelity. Figure 1 illustrates the relationship between altitude of operations and generation time to create suitable M&S products for mission need. The M&S industry spends nearly 60% of its time manually building products to rectify the inadequacies of data sources provided based on a survey of SOFPREP. M&S requires imagery, elevation, features and 3D model datasets that align temporally and positionally. The datasets must also contain accurate metadata that describes the provenance, history and quality of the underlying products.

As defined in the SSG memo, the solution to address the geospatial problem is NGA's FG3D which will support in a dual phased approach. The first phase is to provide a national level archive of geospatial data layers (elevation, imagery, features and 3D models) which is already aligned temporally and is positionally accurate to support mission use cases This national level archive will leverage the community's open standards to ensure interoperability and be

available on all three data networks. The initial seeding of the archive derives from existing OGC CDB content built by USSOCOM and Joint Staff. To access and disseminate the national archive of geospatial data for M&S use, a series of technologies enable the translation of data to desired formats.

The second phase of the SSG memo denotes where NGA will update the initial national archive of data leveraging NGA's global data holdings and a series of automation tools. This effort relies heavily on ensuring the foundation of the data is properly verified to support the M&S community needs. Leveraging verified NGA products that are new to the M&S community ensures confidence and reduces the gap between training and operational datasets thus allowing the operators to train as they fight and fight as they train. NGA developed standards and metrics will quickly assess the automated M&S authoritative datasets and apply confidence to the operator for mission support. Automated tools range from creation of 3D Models aligned to various profiles to verification of the metadata. Knowing the integrity of the data and its alignment back to standards, provides confidence in the overall authoritative source.

## NGA APPROACH TO ADDRESS M&S INTEROPERABILITY

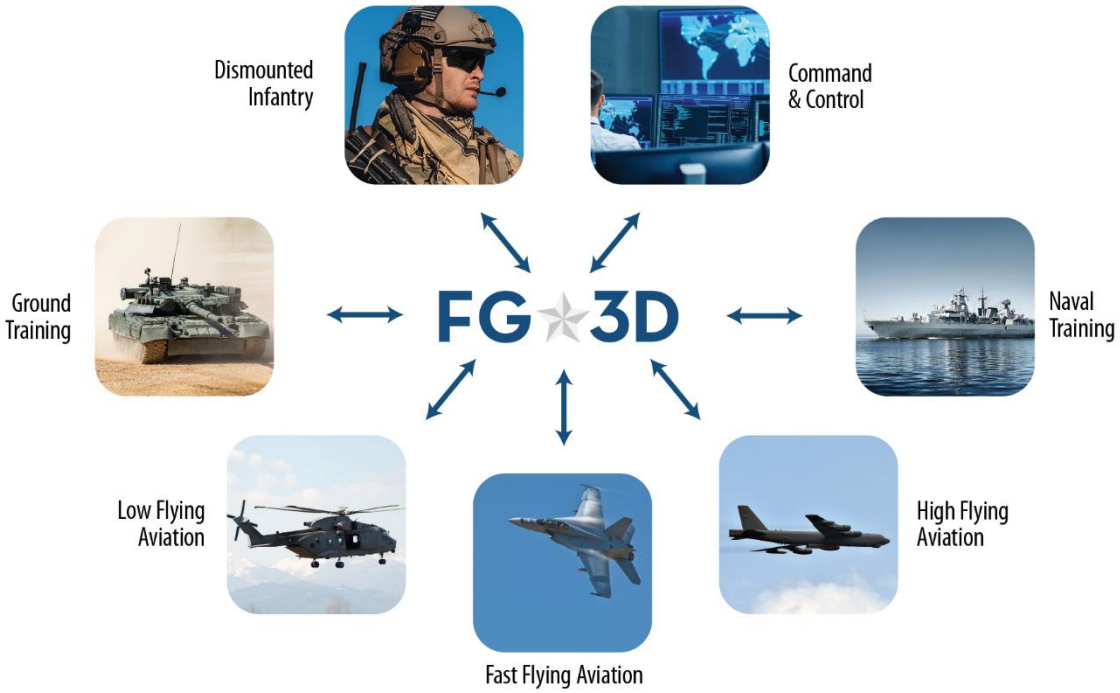


**Figure 2: FG3D Mission**

Figure 2 illustrates the FG3D mission. FG3D aims to deliver 3D Interoperability between a broad set of mission platforms requiring authoritative and standard based data. DoD Directive 5000.59 from 2007 and 2018 regarding M&S management states we should "Maximize the commonality, reuse, interoperability, efficiencies, and effectiveness of Component-specific M&S data, tools and services." FG3D's mission directly aligns to this policy defined by Directive 5000.59 and as described by the SSG memo.

There are concepts that are important to define with respect to the FG3D mission. Interoperability is defined as the ability of a model or simulation to provide services (i.e. 3D data) to and accept services from other models and simulations, and to use the services data exchange to enable them to operate effectively and jointly. Two or more simulations may be in a "fair fight" when differences in the simulations' performance characteristics, with respect to 3D Data, mission functions and entity interactions, have significantly less influence on the conflict than actions taken by the simulation participants.

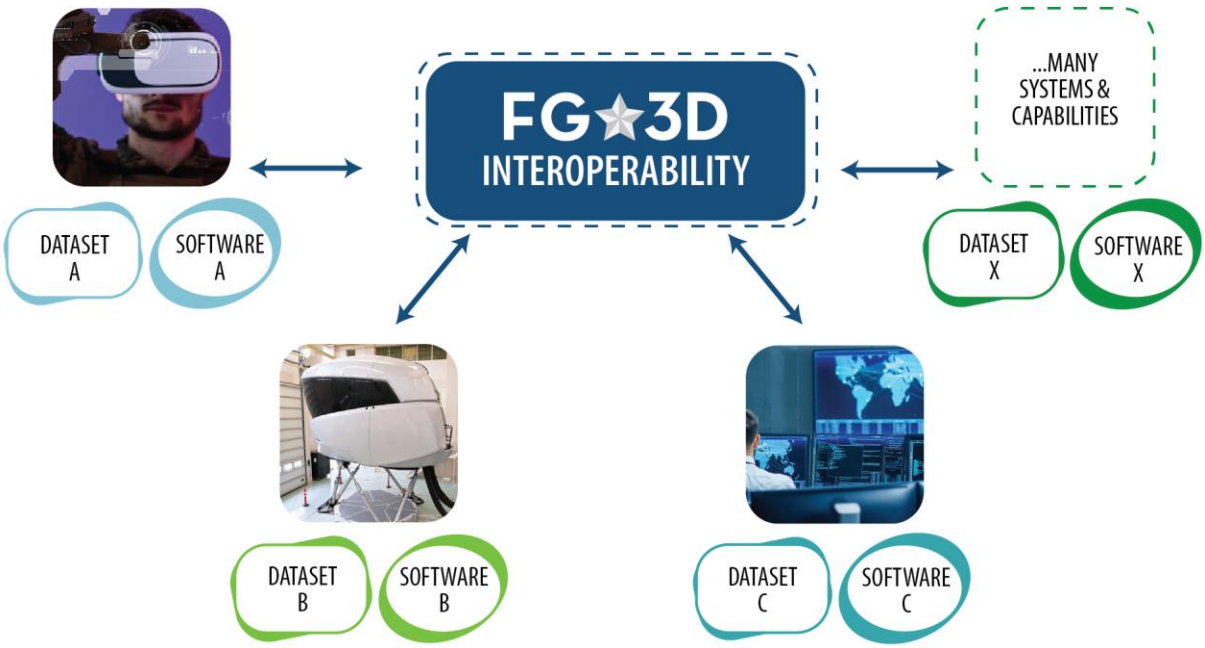


**Figure 3: Interoperability Concept**

Figure 3 illustrates M&S interoperability whereby different datasets and software were applied to a single use case. FG3D improves interoperability with respect to data by providing data sets that meet multiple use cases ranging from VR to simulation to mission command. FG3D is able to meet the needs of a wide variety of use cases because of the use of a common language everyone can use, commonly called standards.

**Architecture**

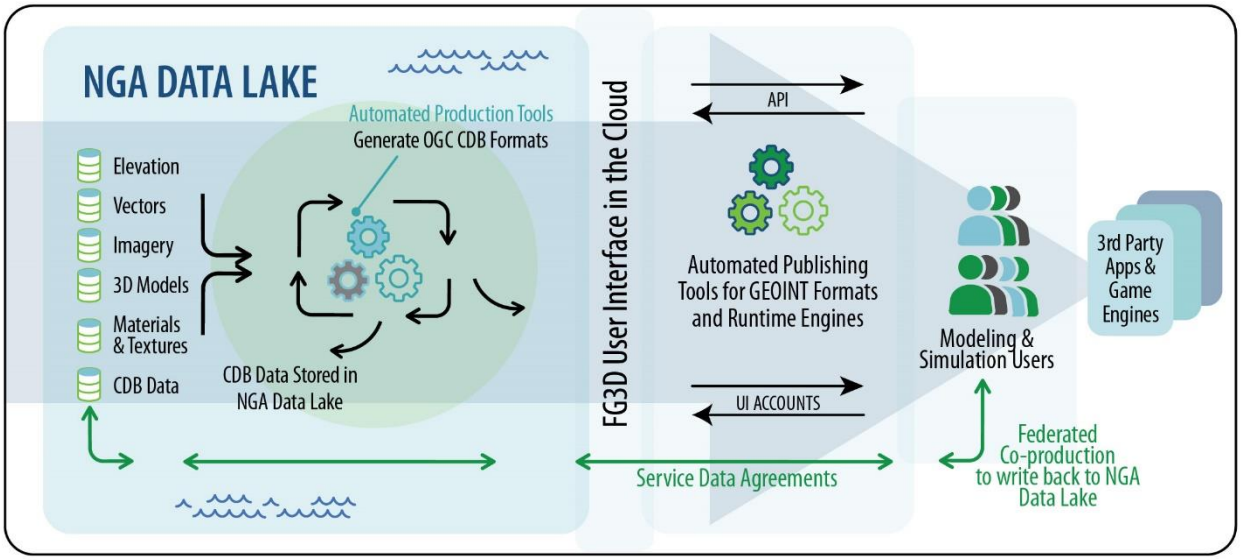


**Figure 4: FG3D Architecture**

FG3D accesses authoritative and non-authoritative data sources for the architecture shown in Figure 4 within the FG3D architecture. The authoritative data sets come from a number of sources in the NGA's holdings with the most prominent being the Open Data Store (ODS). ODS contains a variety of products that are accessible through web APIs

and content management systems. FG3D technologies "shop" within ODS based on the area of interest to determine the most relevant data source to meet a user's request. Non-authoritative data may come from a range of sources with the appropriate distribution caveats and restrictions. It is critical non-authoritative data is verified to ensure its integrity, lineage and accuracy through the FG3D processing pipelines.

The dissemination of M&S products occurs through a modern, easy to use web interface. The user enters a web portal where they are authenticated and authorized as a valid user based on a number of capabilities such as PKI and GEOAxIS. Within the user interface of FG3D, the user (or machine-to-machine interfaces) may select an AOI to request M&S products. Features of the user interface includes: Base layer selection, Zoom in/out, Select area, Distance/area measurement, Coordinate query, Clear selection and Training. There are options as to how one can receive the requested M&S products: leverage existing products within the data lake or generate a new product based on data accessible to the architecture. The second option relies on a series of automation tools to perform various steps ranging from 3D reconstruction to segmentation to validation of the created products. Both options leverage a series of translators and capabilities to reform, transform and conflate underlying data sources to build the derivative 3D and M&S products.

At the time of this writing, FG3D supports twenty-seven different exports. There are twelve different permutations of M&S content in the form of OBJ, FBX, 3D Tiles, I3S, CDB, and VBS. The variations of M&S products include different spatial reference frames and tiling schemas. Fifteen different GEOINT products are also exportable via FG3D in the form of GeoPackage, IMG, TIFF, RPF, DTED, SHP, KML/KMZ, FGDB, FLT, DAE, GLB, FBX, and OBJ.

**Figure 5: 3D Tiles Export from FG3D**

Figure 5 is an example of an FG3D export for San Diego Petco Park AOI. This data export is in the form of 3D Tiles as rendered in CesiumJS. It should be noted that the area of interest support in FG3D ranges for hundreds of meters to hundreds of kilometers.

Android Tactical Assault Kit (ATAK) support is a key element of FG3D development. ATAK is a government off-the-shelf (GOTS) app for Android smartphones. It is available to all government agencies free of charge. ATAK uses GPS, map products and 3D content to give the user a real-time view of an area of interest. FG3D has developed freely-available plugin for ATAK that makes machine-to-machine API calls to FG3D to automate the delivery and download of 3D content to ATAK devices.

Co-production is a unique aspect of FG3D. FG3D is a joint effort between NGA, USSOCOM and Joint Staff. As part of FG3D, NGA will create a 3D M&S Standard Implementation Guide (SIG) that details the 3D content fidelity requirements for different user profiles such as high-flyer or ground training systems. FG3D will mandate co-producers of M&S content to leverage the SIG to improve the quality and fidelity of their content by leveraging defined quality assurance and control steps. Leveraging the NGA guidance will enable co-producers of M&S to create authoritative content for NGA. As co-producers create a common database, FG3D provides a mechanism to automate the publishing of content back to the ODS so that the data is now accessible to other consumers.

**Metadata**

Understanding and identifying error propagation in the creation of 3D products is critical to producing high quality products to enable potential precision engagement applications and point mensuration. It is required to understand the random and systematic error propagation through the processing pipeline. All data has some amount of error, or uncertainty, which must be propagated through processing via metadata to estimate the uncertainty of target coordinates relative to ground truth.

Beyond understanding error propagation, it is critical for FG3D to manage the vast and varied amounts of 3D metadata of both legacy and new assets as well as the ability to discover, map and make searchable all its 3D content. FG3D expands the CDB Standard to support source provenance metadata utilizing the National System for Geospatial-Intelligence's (NSG) metadata foundation standards. FG3D's CDB toolkit enables rapid modification of CDB content and populates the source provenance metadata. This capability also provides mechanisms to run automated quality tests at the point of need prior to upload to NGA's ODS data lake.

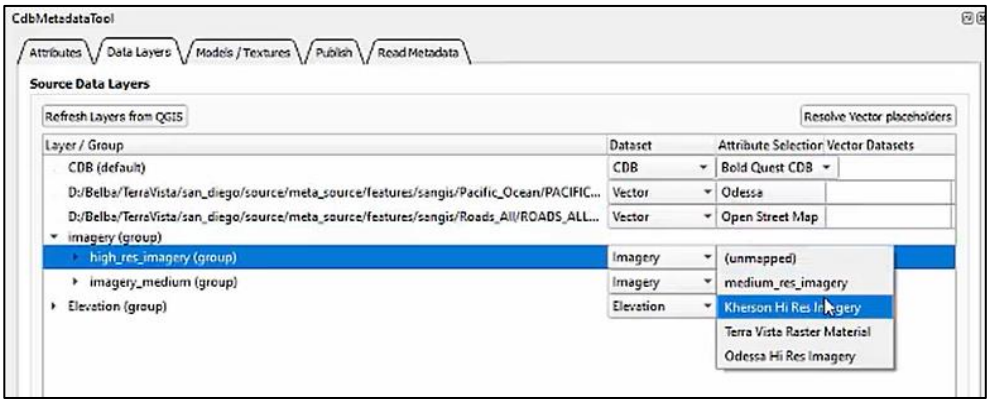


**Figure 6: Metadata Extension for QGIS**

Figure 6 is a screenshot of the FG3D Extension to QGIS to create, modify and publish metadata.

**3D M&S Profiles**

FG3D developed 3D M&S Profiles based off direct operator feedback. 3D M&S Profiles define the characteristics and properties of required M&S products by DoD Services. The M&S Profiles describe the resolution, fidelity, geographic size and other aspects of the needed M&S and GEOINT products representing tactical, mission command, live, constructive, virtual and gaming communities. The profiles serve as a "recipe card" that defines the freshness, resolution, coverage, format, classification and fidelity of the data sources to be used in the recipe. The UI enables the operator to select a desired recipe which in turn initiates a series of automated steps to determine the best available data sources within the vast NGA data holdings. Based on the sources of data available, FG3D will assess expected quality of output by leveraging historical product metrics and current metric tools for these selected data sources, applicable algorithms and geographic area.

The 3D profiles are also leveraged in the services request for M&S data through the NSG Operational Executive (NOX) for official geographical requirements. The services' request for said profiles will trigger production of product gaps to ensure availability for unique use cases where automated tools may not meet mission success.

**OGC CDB**

NGA is leveraging OGC CDB as the data backbone for FG3D for a series of reasons. First, USSOCOM and Joint Staff possess a massive amount of CDB content to seed the initial FG3D enterprise data repository. Second, in a survey of DoD Services, it was found that the most used formats by the Army, Air Force, Navy, Marines, Joint Staff and Special Operations Command are GeoTIFF, Esri Shapefiles and OpenFlight 3D Models. CDB is a mechanism to add rigidity to these commonly used formats across the DoD Services. A third reason FG3D chooses to leverage CDB is the fact that it is an OGC Standard. Leveraging standards is a tenet of NGA to ensure authoritative data.

FG3D will work with the OGC CDB SWG to evolve CDB. Multi-domain operations are a core component of current and future military action where M&S must include cyber, electromagnetic spectrum and space – in addition to the traditional land, sea, and air arenas. To support the 2018 National Defense Strategy and evolving DoD mission, CDB must modernize to address the challenges of cross-domain operations where data supports not only M&S, but Command and Control (C2) systems and tactical devices. FG3D advocates the following advancements in CDB:

- Modernizing data containers by leveraging OGC and Khronos standards and definitions as the mechanism to encode data
- Modernizing data constructs by defining core datasets describing land, sea, air and cyber, electromagnetic spectrum, space and critical infrastructure
- Advancing data constructs by containing self-describing mechanisms to expand datasets to concepts such as human sentiment, patterns of life, and other types of geospatial and non-geospatial concepts
- Maintaining a singular spatial reference system that enable activities such as precision engagement
- Modernizing a taxonomy/ontology that yields maximum interoperability within the Armed Services and IC
- Advancing metadata that yields maximum interoperability within the Armed Services and IC
- Enhancing a foundational structure of the datasets in a form most suitable for content creation, revision and maintenance with standard geospatial tools and C2 systems
- Differentiating the foundational structure of the datasets from Tactical, Gaming, Analytics and M&S use cases of data

Working alongside the DoD and Community on the advancements to the CDB, the working group has made strides to keep up with technology. While NGA retains the raw datasets, the operator down range will need it transmitted in a lossless compression. Advancements in compressions are evolving as technology improves rapidly. Constant assessments are performed to provide recommendations to the future CDB standard to support all cross-domain operations.

**Technology**

As described in a prior section, proprietary tools and standards are historical challenges for interoperability. FG3D is developing all its code as Government Purpose Rights (GPR). FG3D will avoid the utilization of proprietary code. In addition to GPR code, FG3D is leveraging OGC Standards to encode its data. FG3D is developing a series of capabilities to eliminate the barrier of entry to CDB by creating a set of GPR capabilities.

FG3D employs Docker composability concepts, cross-platform approaches and API/Software Development Kits (SDK) in multiple forms enabling the technology to scale, compose and cluster functionality as needed on NGA cloud platforms. Applications are evolving to capitalize on a modern micro-services architecture that encapsulates the functionality of an application into a container that can be independently developed, deployed, scaled, and even replaced seamlessly on the cloud. Docker abstracts the container instantiation, decoupling them from the underlying operating system, helping facilitate the movement to distributed, container-based micro-services.

The CDB Productivity API is a joint project co-developed between NGA, USSOCOM and Joint Staff to instantiate an open capability to generate M&S products, leveraged by FG3D. The CDB Productivity API embodies a set of translation and conflation APIs. The CDB Productivity API leverages Geospatial Data Abstraction Library (GDAL) and Point Data Abstraction Library (PDAL) as its core underlying library. FG3D will provide the CDB Productivity API to NGA stakeholders to enable the read, write and translation of CDB to various file formats and M&S products.

The CDB Productivity API provides an abstract interface to act on data. These data actions range from low-level primitive data objects to data collections to files. The data actions of the CDB Productivity API today include capabilities like generating a mesh via triangulation from a heightmap, generating UV coordinates for a texture on a mesh, generating LODs and attribution mapping. The capability is currently deployed in conjunction with SOCOM Federated Co-production. FG3D is working to expand the CDB Productivity API to include functionality like conflation, registration and error detection.

To maintain compliance with OGC CDB, FG3D developed the CDB Validator which operates as a Docker container that performs automated quality checks to ensure the integrity, content, and compliance to standards defined in the OGC CDB specification version 1.2. FG3D will enhance the current capabilities to ensure compliance with OGC CDB future standard updates with the CDB Toolkit.

The FG3D Web UI provides users and developers the ability to visualize data in both 2D and 3D. For 2D visualization, FG3D leverages OpenLayers as a core framework. For 3D visualization, FG3D uses Three.js in editing environments and Cesium.js in performance/streaming environments. Each framework (OpenLayers, Three.js and Cesium.js) offers

a mechanism to generate visualization plug-ins (i.e. file handlers for specific file types) that deliver an agnostic visualization environment. Natively, the FG3D UI supports CDB, 3D Tiles, OBJ, FBX, Web Map Service (WMS), Web Map Tile Service (WMTS), Web Feature Service (WFS) and Web Coverage Service (WCS). FG3D employs React as the core framework to give a common look and feel between 2D and 3D. The core React framework will contain common controls regardless of being in 2D or 3D mode, and the ability to create custom developer defined buttons. This Web UI enables users to upload data back to FG3D for adjudication and usage within the authoritative FG3D data holdings.

For desktop purposes, FG3D has developed an extension for QGIS. QGIS is a free, open source Geographic Information System (GIS) application. QGIS contains a plugin and extension architecture to enable the addition of new concepts and capabilities. FG3D has created a QGIS FG3D extension based on the CDB Productivity API that enables a user to view, modify or translate CDB content via QGIS. Currently deployed and installed with SOCOM for federated co-production with operators and FG3D.

To automate the construction of 3D from authoritative data sources and conflation, FG3D leverages a series of micro-services developed by Joint Staff, USSOCOM, US Army and other agencies. FG3D integrates, extends and reuses Joint Staff J7's Terrain Generation System (TGS), USSOCOM's Rapid 3D, U.S. Army's TEXPERT and U.S. Army's Assimilation of Sources for a Cohesive Environment Description (ASCEND) capabilities.

FG3D leverages the Joint Staff J7's TGS. TGS is a web-based set of services that provide M&S ready data and scenario development tools to the DoD Enterprise to support Joint and Service theater level constructive training. TGS leverages unique data repositories and tools to generate training scenario initialization files. TGS utilizes OGC CDB and geospatial web mapping interfaces to share and distribute simulation products and geospatial data. TGS promotes sharing, reuse and utility by storing geospatial and simulation data sets in non-proprietary formats structured in fashion to facilitate rapid access, rendering and visualization.

FG3D leverages USSOCOM Rapid 3D cloud-based framework. Rapid 3D orchestrates the execution of micro-services, where each micro-service is responsible for the transformation, conflation, conversion, and translation of data. The Rapid 3D architecture supports multi-domain cloud for co-producing, hosting and disseminated 3D terrain across DoD/IC and coalition partners. The architecture houses a core library of functionality that enabled the integration and expansion of artificial intelligence and machine learning algorithms for rapid exploration and dissemination of 3D M&S data. Rapid 3D contains Geo-Registration capabilities that automate the conflation of imagery and sensor data in the construction of point clouds for segmentation to digital elevation models and 3D features complete with M&S relevant attribution. The Rapid 3D architecture was designed to elastically scale within a cloud environment enabling new CDB data creation and dissemination.

FG3D leverages capabilities from Applied Research Laboratories at University of Texas Austin (UT). UT Austin has developed TEXPERT (TEXas Point cloud Exploitation Research Toolbox) as a GOTS solution for Automated Feature Extraction (AFE) of 3D input point cloud data sets. TEXPERT is a suite of independent software modules, each designed to solve a discrete part of the AFE process. Currently, TEXPERT modules can be combined to form an AFE pipeline that provides an end-to-end solution for the transition from a 3D input point cloud to a 3D mesh output. Alternatively, TEXPERT modules can be used independently or combined with other AFE algorithms depending on the desired output and operational or training objective. TEXPERT contains processing pipelines for both modules LiDAR and space-based Electric-Optical (EO) stereo-photogrammetry derived point clouds. Output data products include labeled and segmented point clouds, Digital Surface Models (DSMs), Digital Terrain Models (DTMs), feature shapefiles, and feature meshes. TEXPERT is developed on the RHEL8 Linux platform in C++ and Python and is openly available to Government customers via Docker container, source code and/or Linux package managers. TEXPERT pipelines support integration with cloud computing environments through the use of PDAL filters and command line interfaces. Modules within TEXPERT are architected to optimize processing speed and efficiency and take advantage of parallel computing capabilities where available.

FG3D integrates the US Army's ASCEND capabilities and associated micro-services automatically conflate disparate data into 3D models that can be used for comprehensive intelligence assessments. ASCEND automates the conflation process by creating rulesets that codify how users manually combine disparate and conflicting datasets. For example, users can prioritize high accuracy buildings over those from more recent data collects. Alternately, in the same build,

users could set rules to prioritize trees from the most up-to-date sources. ASCEND sets default rules based on NGA best-practices, but the rules are configurable to accommodate specialized use cases.

The FG3D advancements from the series of micro-services developed by Joint Staff, USSOCOM, U.S. Army and other agencies are put back into the services software's baseline and distributed back to those partners for integration. The sharing of code and group enhancements have allowed for more rapid integration and community closing the interoperability gap between M&S data together.

## SUMMARY

The DoD issued a memorandum via the SSG for the USD calling for a national level archive of simulation ready content to address simulator interoperability between the DoD and IC communities. NGA is addressing simulator interoperability by building FG3D. The FG3D mission is to ensure geospatial data interoperability by making authoritative M&S content accessible on US Government networks.

FG3D offers many benefits. FG3D automates the construction of 3D from authoritative data sources, enables users to create and upload custom content, automates the conflation and subsequent validation of 3D content, and automates and disseminates 3D products in commonly used formats. FG3D support interoperability by curating and disseminating data suitable of a broad mission set.

The future for FG3D includes many things. FG3D will increase the number of M&S products it supports by extending the CDB Productivity API. FG3D will incorporate more 3D Reconstruction and Automated Feature Extraction algorithms to enhance its data fidelity and freshness. FG3D will work with the US Army to ensure FG3D and OWT align on core concepts and principles to enable data interoperability. Finally, FG3D will share functionality through SDKs and APIs, and allow for integration into various mission support systems and for brokering of data between the warfighter communities.

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