# One World Terrain's Well-Formed Format

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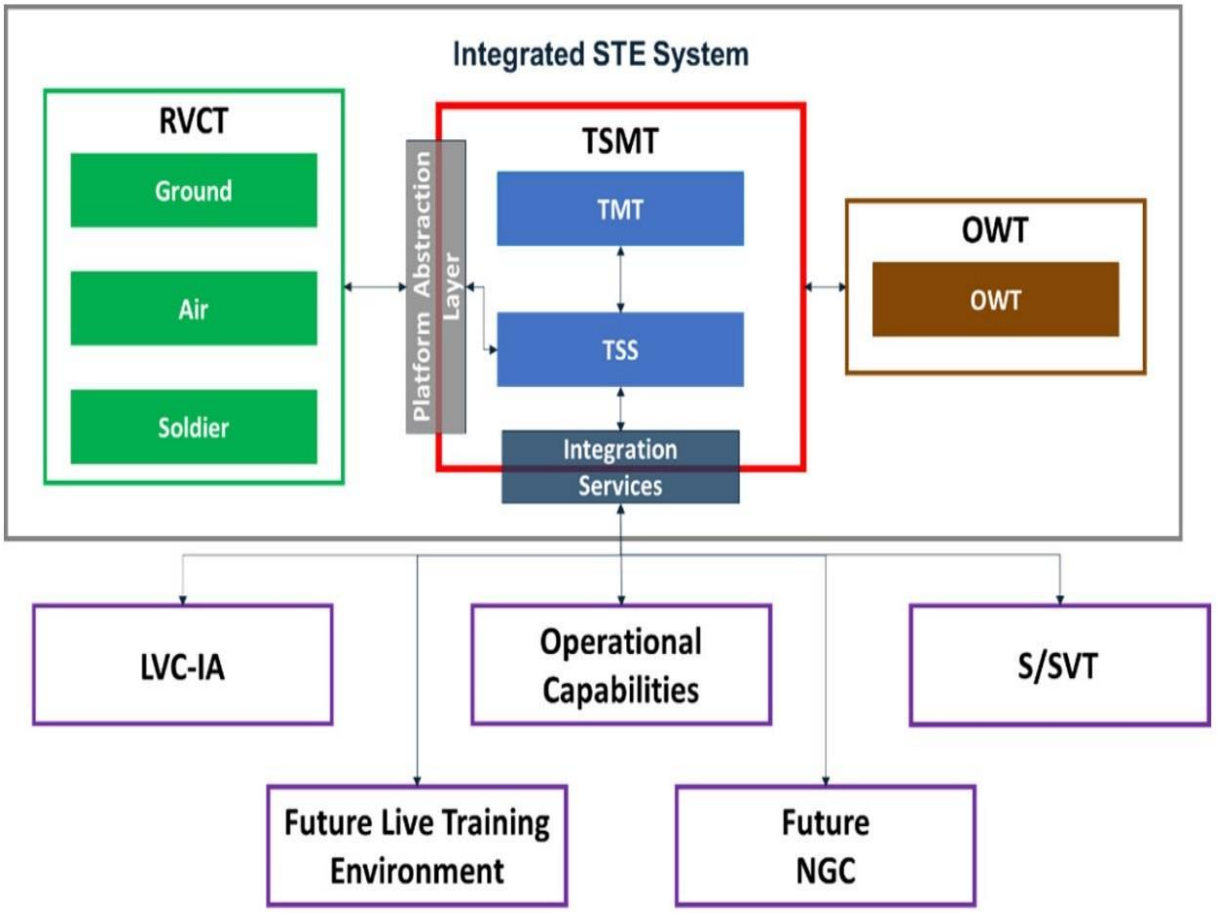
v01

## Outline

- Introduction
  - One World Terrain Requirements
  - One World Server Components
  - OWT Production Activities
- Well-Formed Format
  - 3DTiles
  - With Extensions
- Comparison with other Standards
- OWT Future Development Activities
- Initial Lessons Learned

# Introduction

- US Army's STE provides interconnected training system
  - squad through commands train in live, virtual, constructive, and gaming domains
  - conduct realistic cognitive, collective, multi-echelon and multi-domain combined training
  - immersive and intuitive training to support changing operational environment
- STE will provide common simulation components, including
  - Training Management Tools (TMT) and
  - Training Simulation Software (TSS), supported by a global
  - One World Terrain (OWT)



# OWT Requirements

- **One World Server (OWS)** System
  - Import, Processing, Export and Delivery of the OWT Data
- **One World Terrain (OWT) geospatial data**
  - Delivery to STE Training System Software (TSS) and Training Management Tool (TMT)
    - In the OWT Well Formed Formats (WFF)
  - Delivery to STE-external consumers
    - In traditional formats (sometimes called the ”Well Known Formats”)
  - **3D Geospatial Terrain Data**
    - Locations worldwide
  - **3D Models**
    - Moving, relocatable, vegetation, textures and clutter 3D models
- **OWT Well Formed Format (WFF)**
  - Format specification for 3D geospatial data, comprehensive training support
  - Open standard, based on
    - OGC 3DTiles with extensions
    - Kronos Group glTF formats (GL Transmission Format) with extensions
    - IETF GeoJSON
    - AGC Ground-Warfare Geospatial Data Model (GGDM)

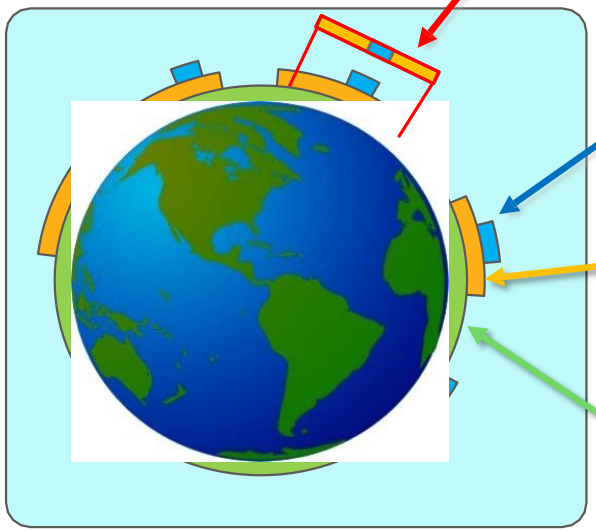
# OWT Production Activities - Data Stratum Concept

OWT Stratum - a geographic area or feature component that is a gradation of resolution in the One World Terrain ordered system

High

Resolution

Low



OWS data stored in Stratum of the OWT Base Globe, OWT 3D Foundation regions and OWT 3D Insets

## OWT STE 3D Terrain Pack

- **STE 3D Terrain Pack is best available data in the selected area of interest integrated into a single unambiguous dataset**
- Composed of OWT 3D Foundation Data providing regional coverage with OWT 3D Insets representing local and site coverage
- Enhanced with procedurally refine content to support modeling, simulation and training

### OWT 3D Insets – Local/Site Coverage

- Provides higher resolution terrain data – buildings for dismounted soldier-based training
- Provides higher resolution environmental data including buildings for ground-based training
- Provides landmark models for navigation aid for air and ground vehicle-based training
- Provides vertical obstruction and cultural clutter
- Available on demand
- Based on Drone collects, Bing 3D Data, Army Reuse, Buckeye, Procedural Enhanced, etc.
- Represented in a 3D Terrain Mesh; OGC 3DTiles/glTF with extensions as the OWT Well Formed Format
- Composed of:
  - Better than 50cm Imagery
  - Better than 50cm Elevation
  - Better than 50cm LULC Classification
  - Building, Bridge, Landmark Models
  - Road, Water, Building Vectors

### OWT 3D Foundation* – Regional Coverage

- Provides positional accuracy data (3meter SE90) to ensure real world correlation
- Provides satellite imagery derived 3D Terrain Model decorated with extracted buildings and bridges for air-based training
- Provides background to 3D insets
- Used for georegister higher resolution insets to ensure correlation of insets
- Available on demand
- Based on Maxar's Authoritative 3D Surface Model and NGA/industry authoritative sources
- Represented in a 3D Terrain Mesh; OGC 3DTiles/glTF with extensions as the OWT WFF
- Composed of:
  - 50cm Satellite Imagery
  - 50cm Elevation, 15m Bathymetry
  - 50cm LULC Classification
  - Building, Bridge, Landmark Models
  - Road, Water, Building, Point, Curve and Surface Vectors

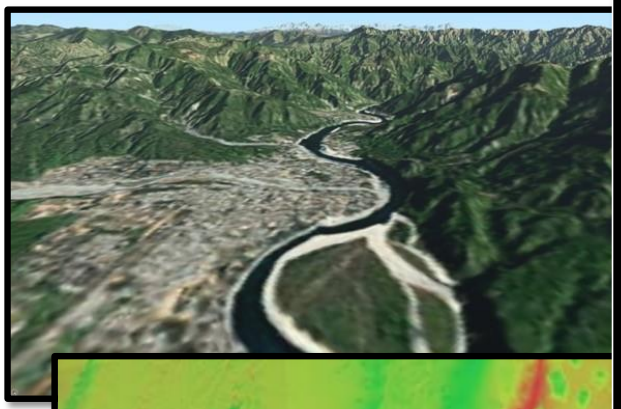
### OWT Base Globe – Global Coverage

- Provide worldwide coverage of lower resolution data
- Provides global context for selection of area of interest
- Provides vector data for decorating the Base Globe with 3D procedurally generated content
- Pre-loaded on the Point of Need (PoN) systems
- Based on traditional sources
- Less than 2TB on disk
- Represented in a 3D Terrain Mesh; In OGC 3DTiles/glTF with extensions as the OWT WFF
- Composed of:
  - ~15m Imagery
  - ~30m Elevation, Bathymetry
  - ~30m Land Use Land Cover (LULC) Classification
  - Road, Water, Building,… Point, Curve and Surface Vectors
  - 3D Models

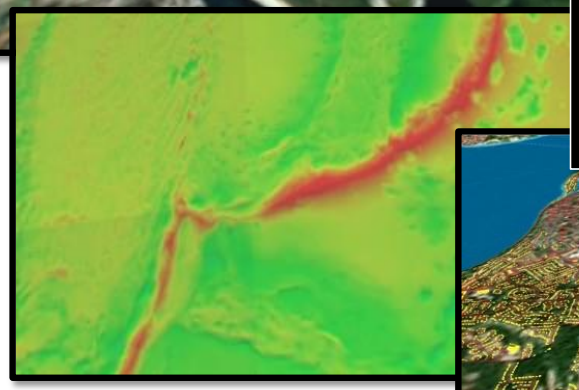
# Stratum Data - OWT Base Globe – Global Coverage

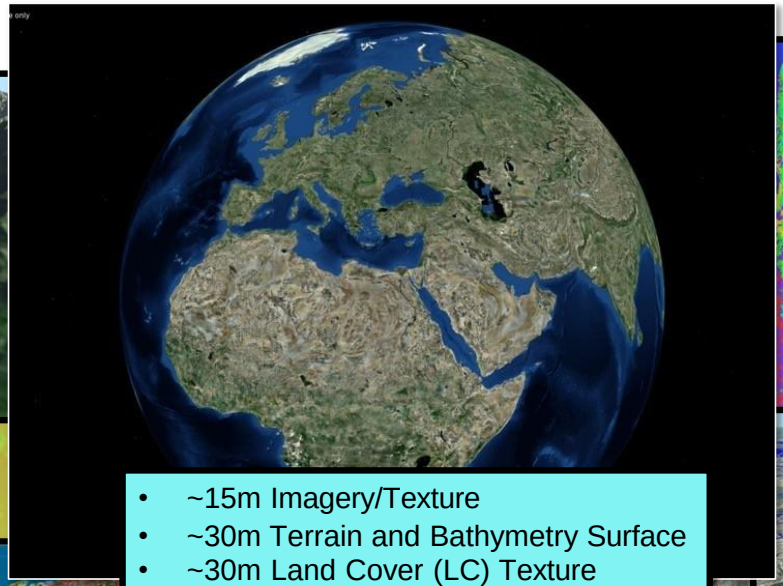
ONE WORLD TERRAIN

**Imagery (draped over) Terrain Mesh**



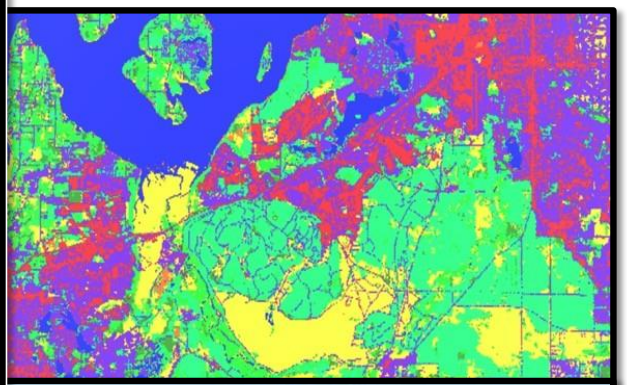
**with integrated Bathymetry**

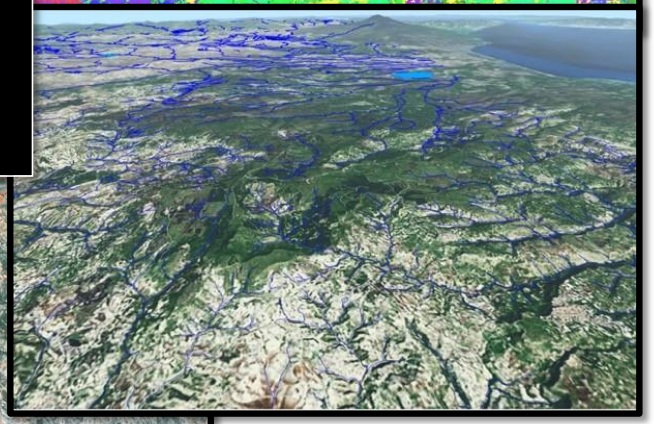




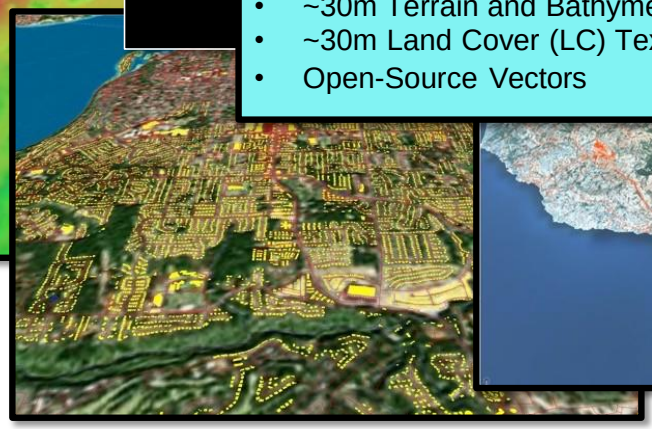
- ~15m Imagery/Texture
- ~30m Terrain and Bathymetry Surface
- ~30m Land Cover (LC) Texture
- Open-Source Vectors

**Land Cover**

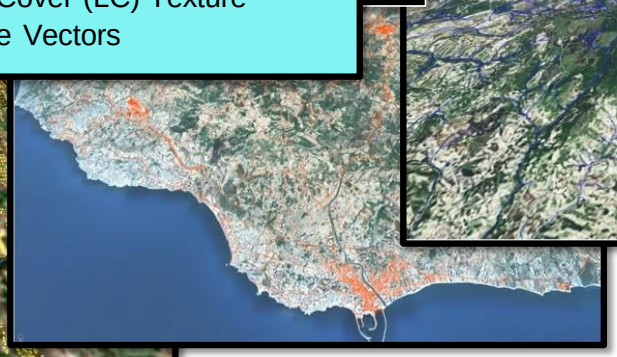




**Waterbodies, Waterways**



**Building Footprints**



**Roads**

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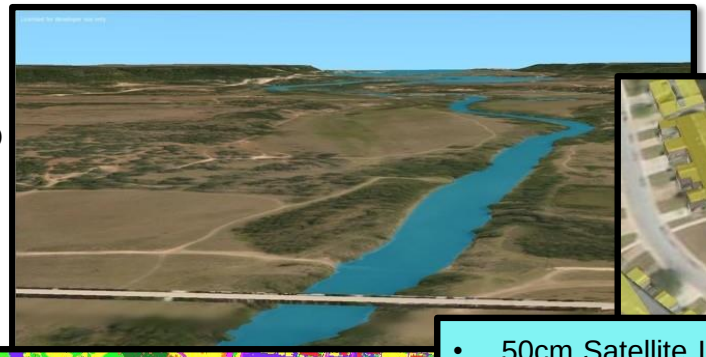
# Stratum Data - OWT 3D Foundation – Regional Coverage

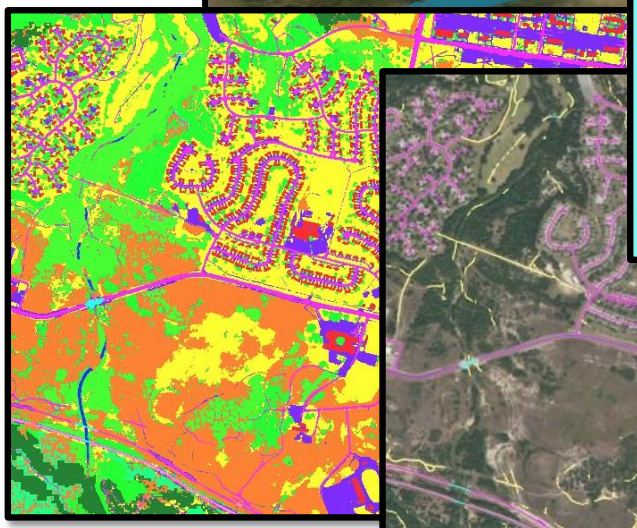
Waterbodies and Bridge 3D Extraction



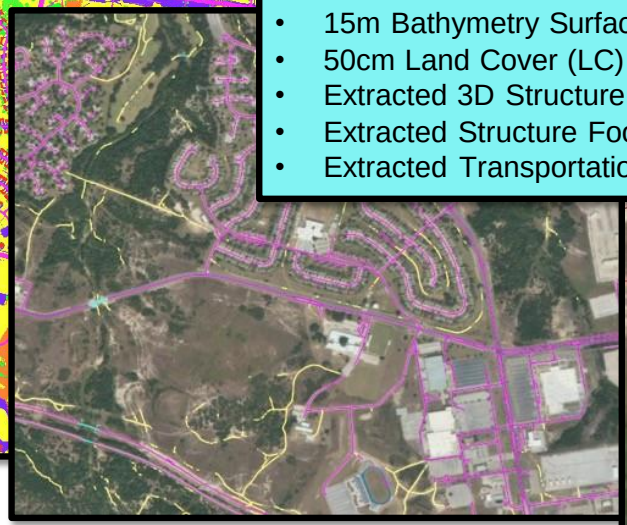
Building Footprints

Building Extractions

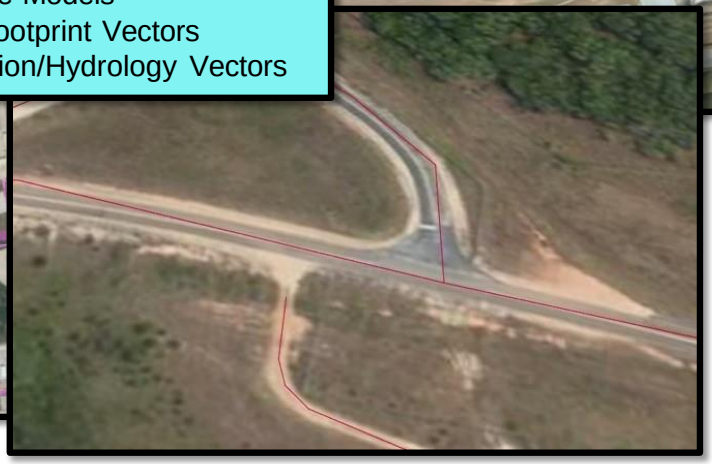
- 50cm Satellite Imagery/Texture
- 50cm 3D Terrain Surface
- 15m Bathymetry Surface
- 50cm Land Cover (LC) Texture
- Extracted 3D Structure Models
- Extracted Structure Footprint Vectors
- Extracted Transportation/Hydrology Vectors



Land Classification



Road and Rail Extraction



Conflate Attributes

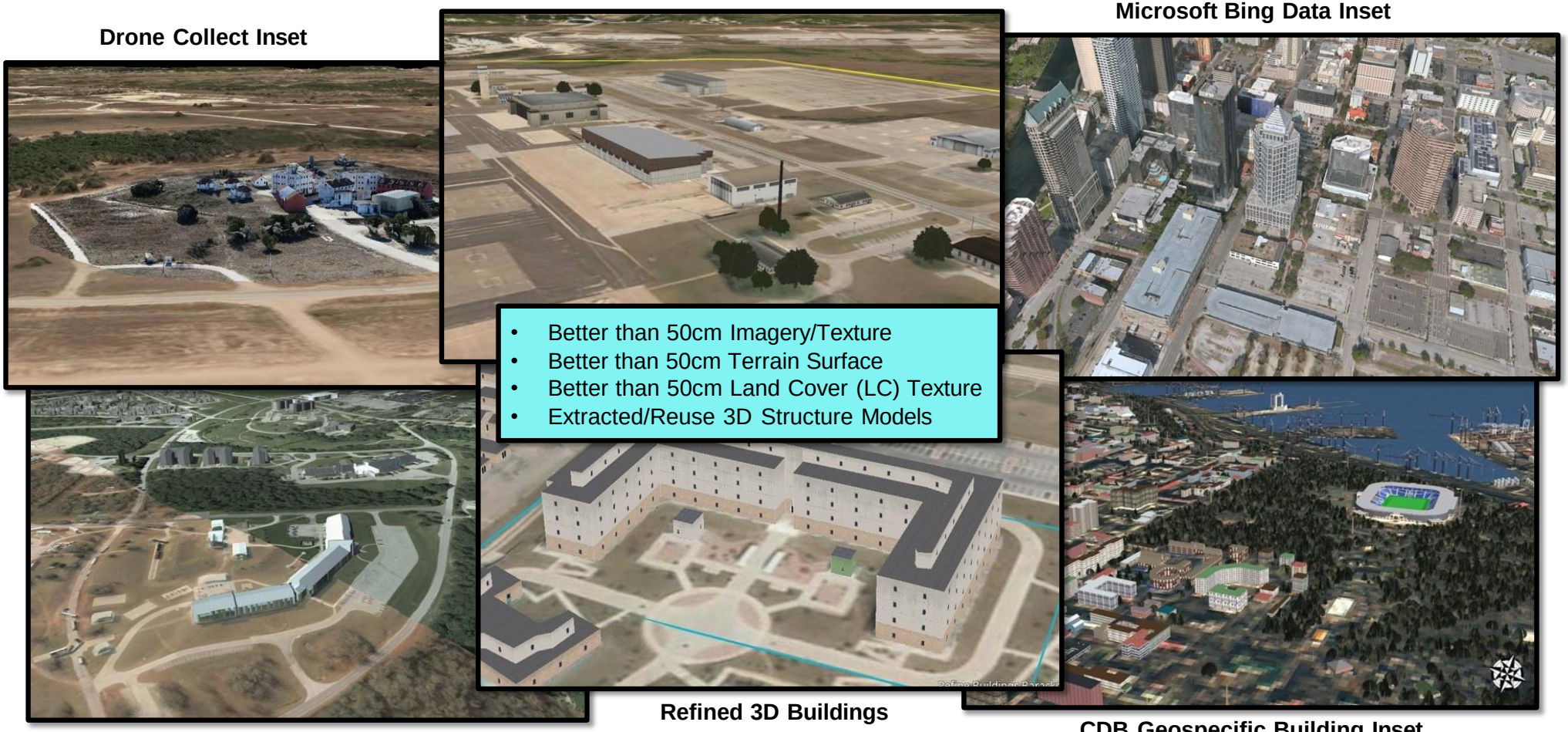
# Stratum Data - OWT 3D Insets – Local/Site Coverage

ONE WORLD TERRAIN

**SE Core Building and Airports Inset**

**Drone Collect Inset**

**Microsoft Bing Data Inset**



- Better than 50cm Imagery/Texture
- Better than 50cm Terrain Surface
- Better than 50cm Land Cover (LC) Texture
- Extracted/Reuse 3D Structure Models

**Buckeye Inset**

**Refined 3D Buildings**

**CDB Geospecific Building Inset**

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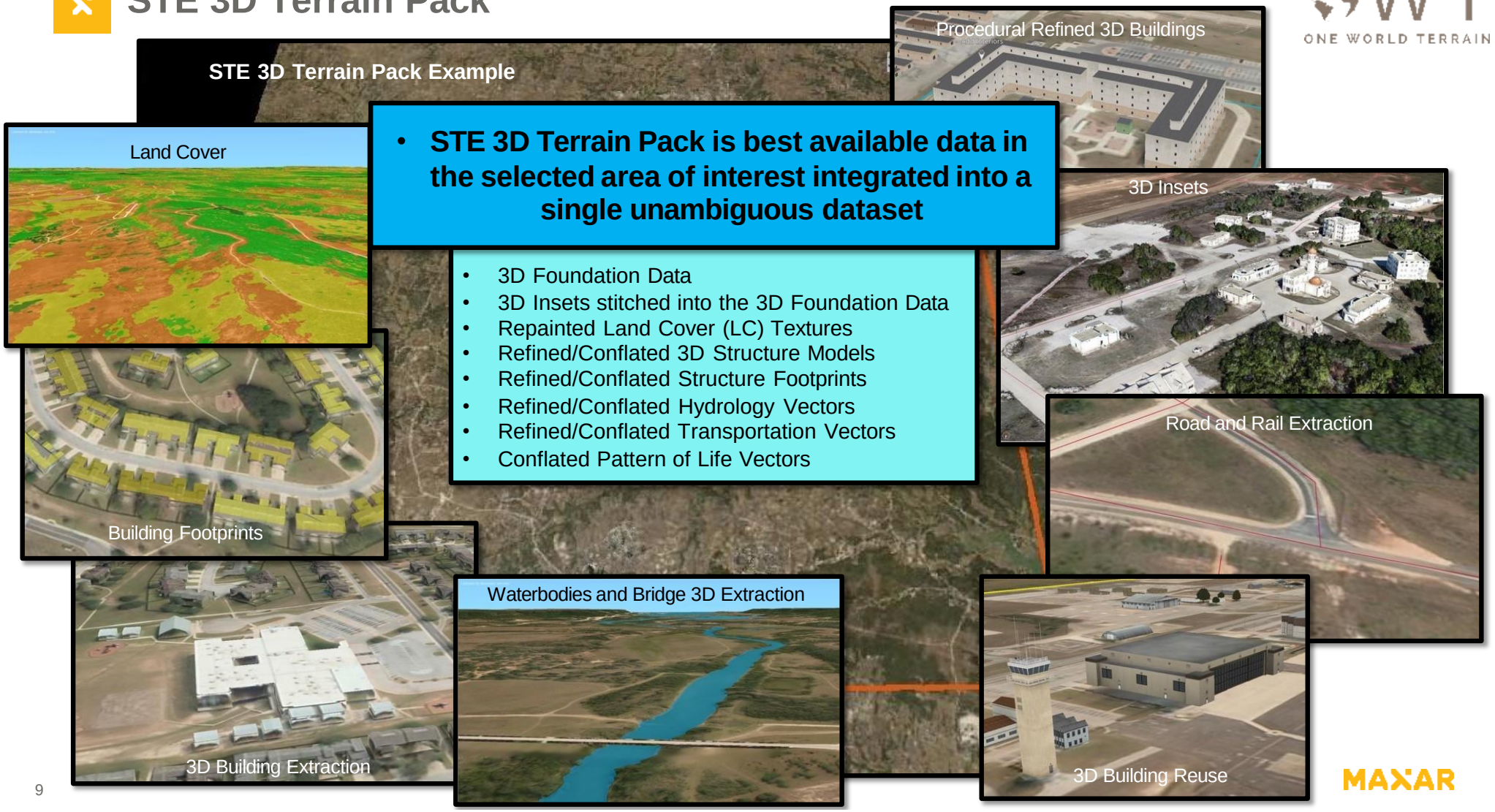
# STE 3D Terrain Pack

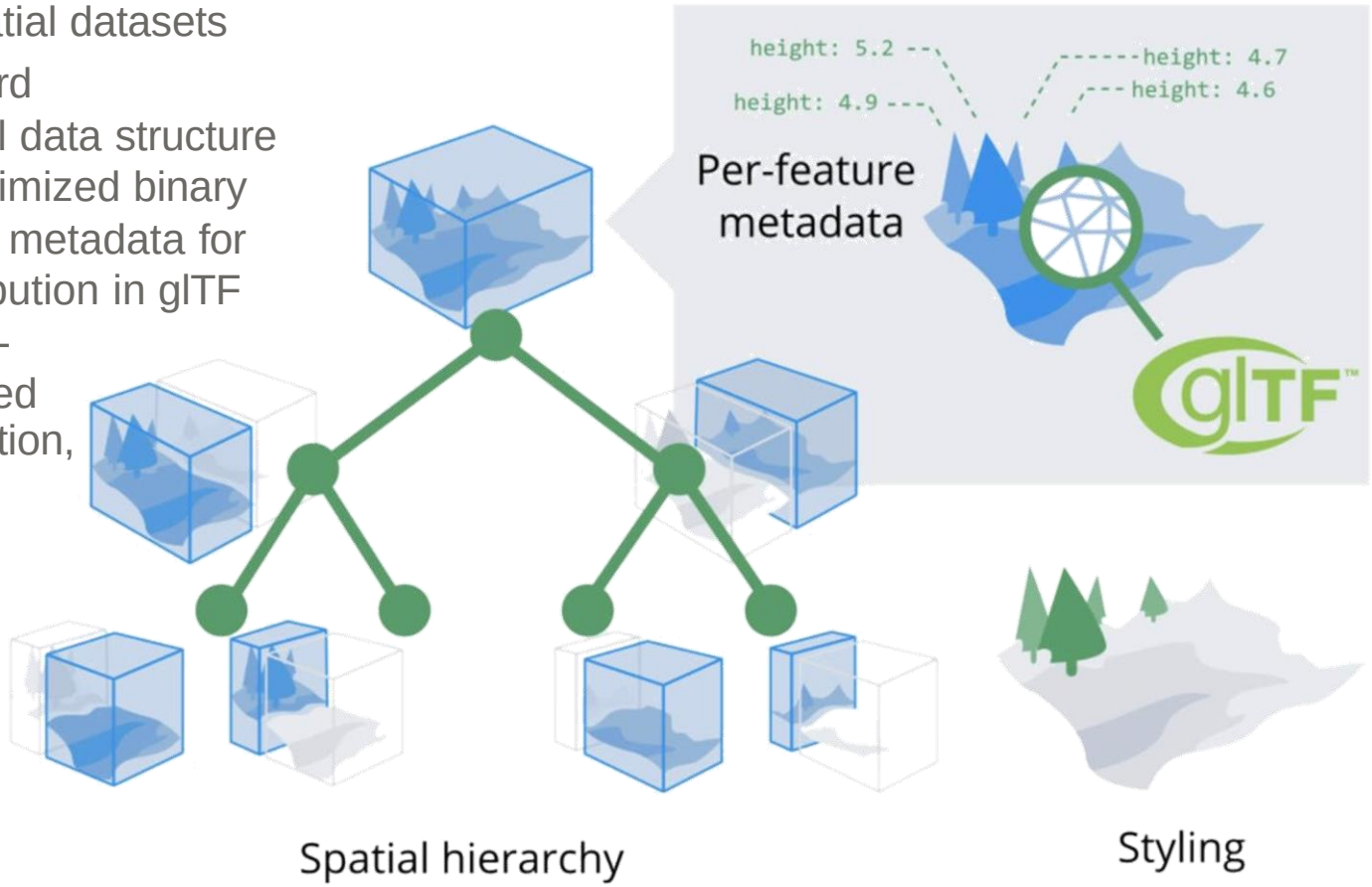



- **STE 3D Terrain Pack is best available data in the selected area of interest integrated into a single unambiguous dataset**

- 3D Foundation Data
- 3D Insets stitched into the 3D Foundation Data
- Repainted Land Cover (LC) Textures
- Refined/Conflated 3D Structure Models
- Refined/Conflated Structure Footprints
- Refined/Conflated Hydrology Vectors
- Refined/Conflated Transportation Vectors
- Conflated Pattern of Life Vectors

# OWT Well-Formed Format - 3DTiles

- Efficient streamable runtime format for massive heterogenous 3D geospatial datasets
- OGC Community Standard
- Combines flexible, spatial data structure in JSON with runtime optimized binary payloads with embedded metadata for vertex/polygon level attribution in glTF
- Explicitly expressed (well-formed) usage with defined
  - levels of detail organization,
  - coordinate systems,
  - specific tiling scheme,
  - layers,
  - features, and
  - attribution



# OWT Well-Formed Format - 3DTiles and glTF Extensions

- Vector Feature Addition
  - introduction of a vector data standard
  - GeoJSON to represent geographic information system (GIS) data
  - supports the reasoning systems and map generation
  - supports the pattern of life simulation requirements
- Metadata Expansion
  - enhance the geometry mesh (giving meaning to the mesh)
  - supports the content required for reasoning systems and sensor simulations
- Implicit Tiling
  - implicit tiling scheme
  - well-defined tiling scheme simplifies and optimizes the data organization

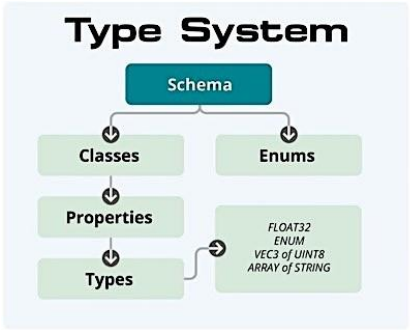
- 3DTiles Next and glTF Update
  - OWT is committed to make WFF available to the community
  - OWT Extensions available on the Cesium website
  - OWT 3DTiles extension included in 3DTiles Next proposal under consideration at OGC
  - OWT glTF extensions reviewed for consideration for the next version of glTF

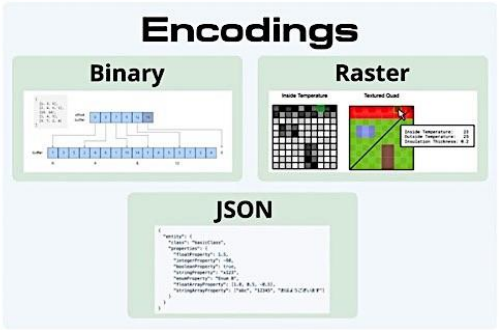
# 3DTiles and glTF Extensions Vector Feature Addition

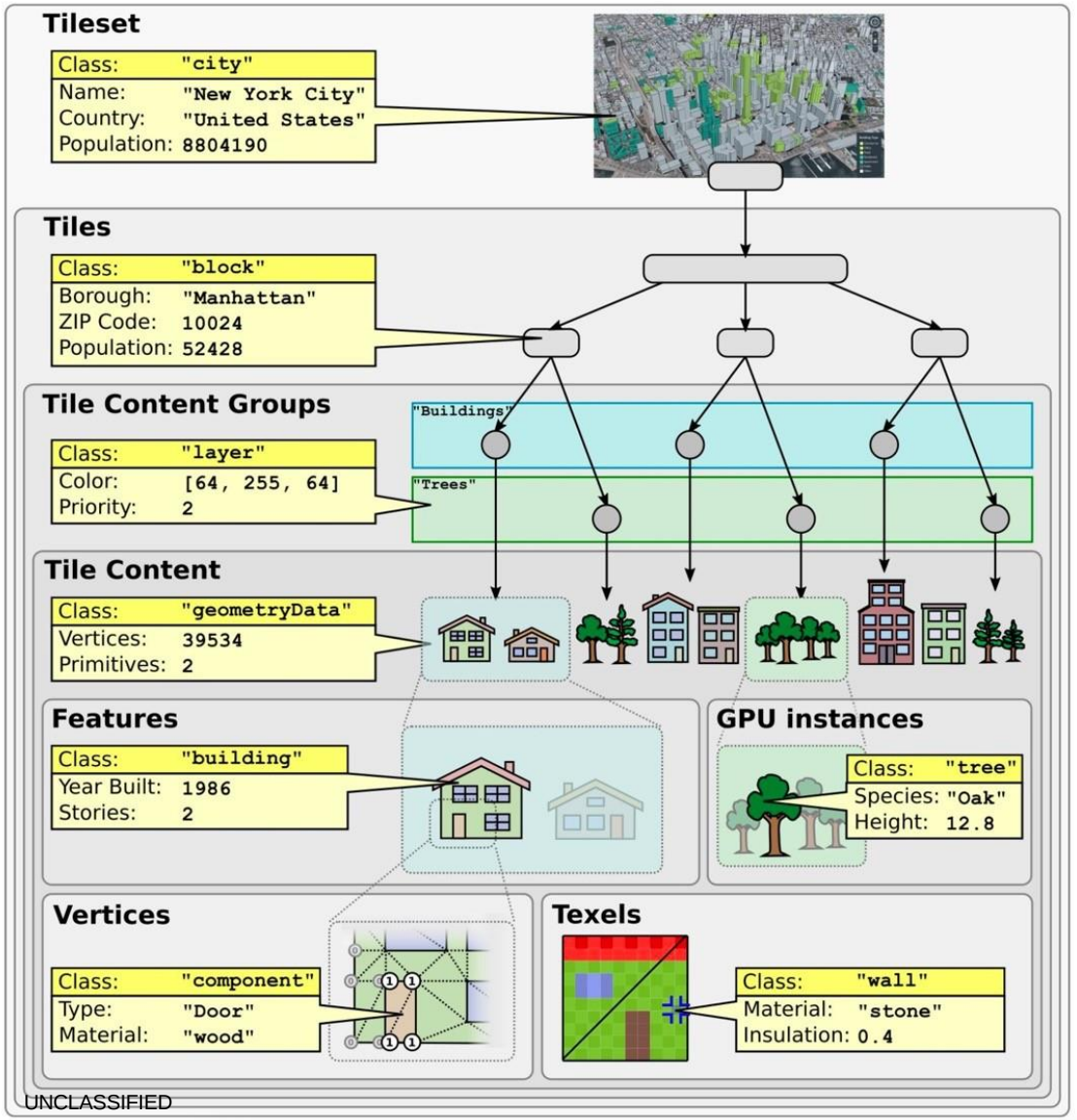
- Added vector data at a single level of the tile organization
- Provides feature data in a vector form to compliment the metadata in the geometry mesh
- Data can come from the AI and Machine Learning extracted vectors or conflated vectors from secondary source
- Provides the ability to represent abstract features (e.g. political boundaries, administrative regions) and point features (e.g. map names, landmark locations) that are not explicitly represented in the geometry mesh
- Internet Engineering Task Force (IETF)
- GeoJSON (Geographic JavaScript Object Notation) is a geospatial data interchange format based on JSON
- GeoJSON supports points, lines, polygons, multiple points, multiple lines, multiple polygons, and collections

# 3DTiles and glTF Extensions Metadata Expansion

- Augment real-world data with semantics from AI/machine learning and conflated sources
  - Metadata at many granularities
  - Decoupled design: semantics, type

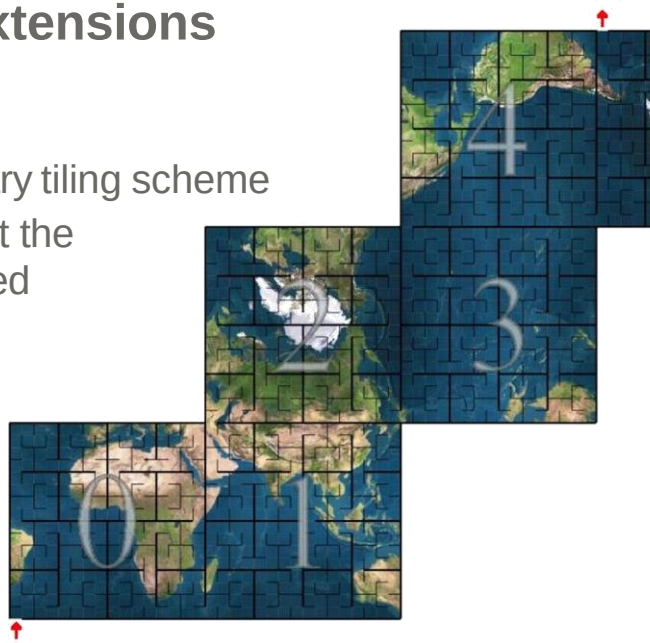



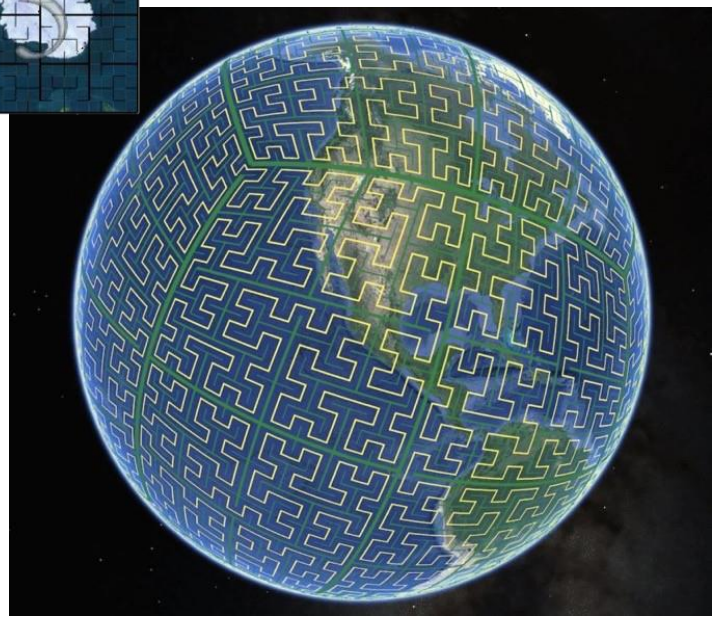



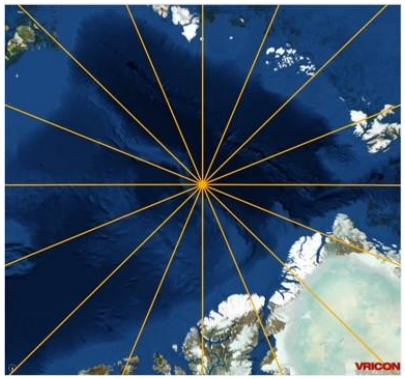
# 3DTiles and glTF Extensions
# S2 Geometry

ONE WORLD TERRAIN

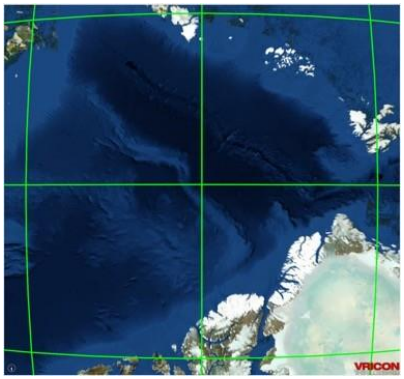
- OWT chosen the S2 Geometry tiling scheme
- Avoids excessive distortion at the poles (latitude/longitude-based scheme issue)
- S2 Geometry facilitates random access, accelerates spatial queries, provides efficient traversal at runtime, and enables partial updates for changing scenes.






Geodetic Grid




S2 Grid

Poles

- Each cell uniquely identified by 64-bit S2CellId
- S2 cells numbered to maximize locality of reference for spatial indexing
- S2 cells are ordered sequentially along a space-filling curve
- Six Hilbert curves linked together to form a single continuous loop over the entire sphere.





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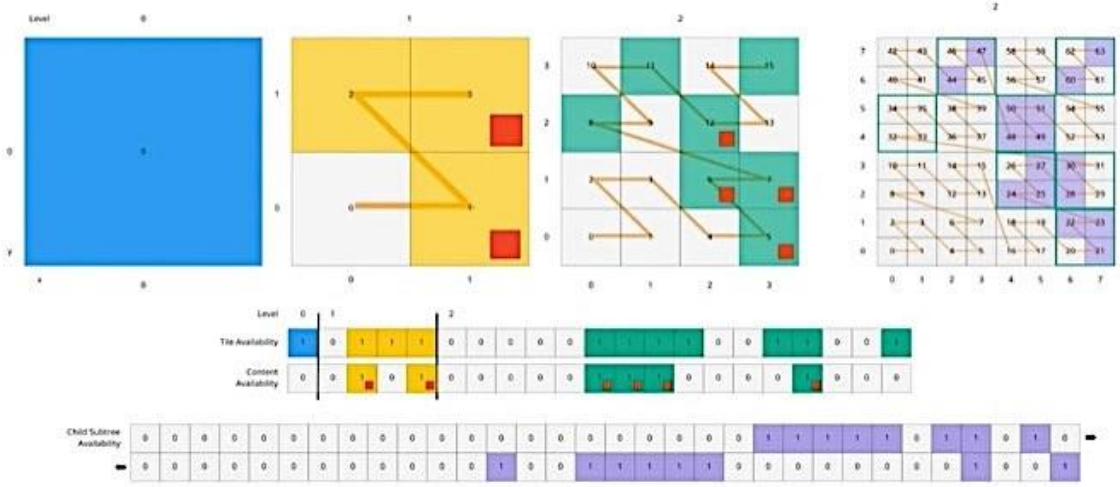
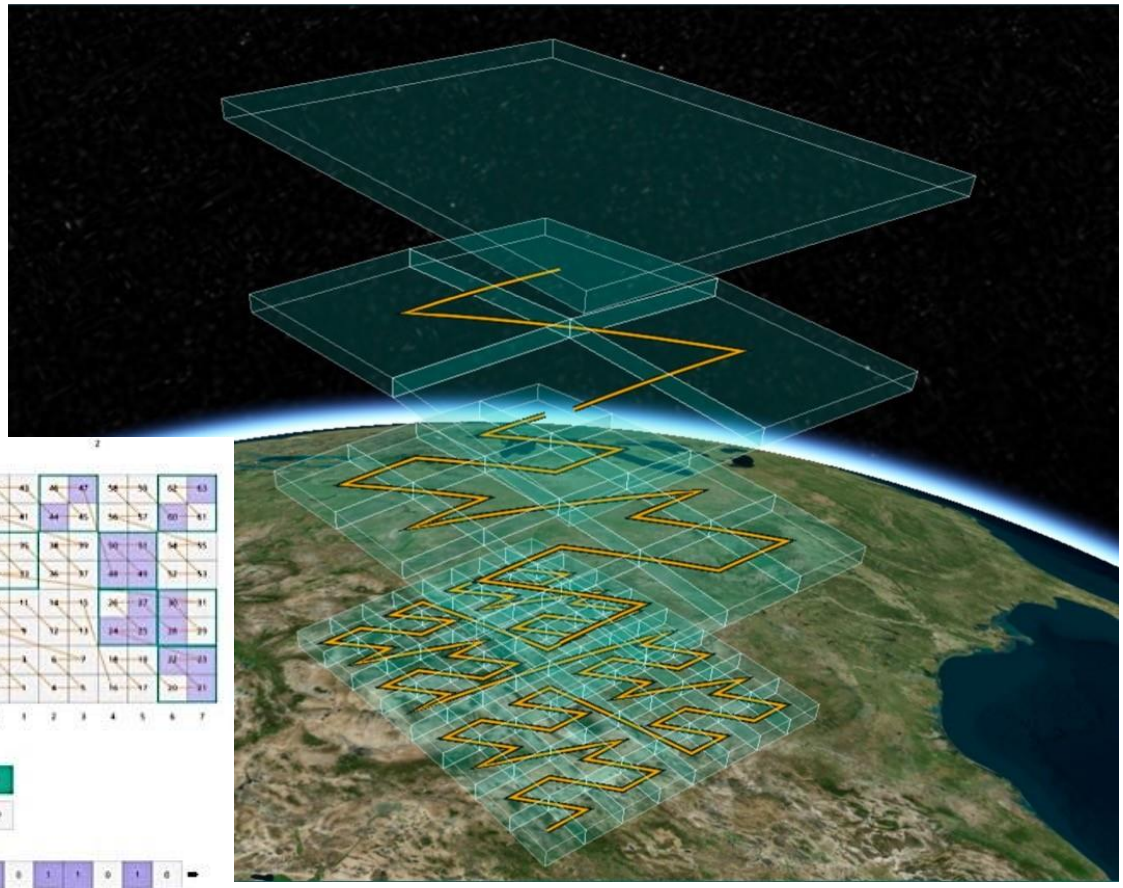
# 3DTiles and glTF Extensions
## *Implicit Tiling*

- 3DTiles supports explicit tiling, providing great flexibility in data organization,
- OWT objective is global coverage with a single, well define organization
- Implicit tiling added to reduce the overhead of defining a global organization of data
- Hilbert curve used to indicate depth





# Comparison with other Standards


- Comparison with other Standards
  - Open Geospatial Consortium CDB
  - Simulation Interoperability Standards Organization (SISO) Reuse and Interoperation of Environmental Data and Processes (RIEDP)
  - Open Geospatial Consortium 3DTiles
  - U.S. Army Synthetic Training Environment (STE) One World Terrain (OWT) Well Formed Format (WFF)
    - 3DTiles with extensions




# OGC CDB

- Defines “standardized model and structure for a single, ‘versionable,’ virtual representation of the earth.”
- Initially sponsored by US SOCOM and developed by Presagis and CAE,
- “ownership” transferred to OGC in 2018 - owned as an OGC standard
- Actively maintained within a dedicated OGC standards working group (SWG), with updates being developed by a committee with member/quorum consensus
- Data organization is defined by specification
  - Identified based-on well define folder names and file names
  - Augmented with metadata within file formats and in external files
  - Based on existing “well known” industry formats
  - Data labeling using Feature and Attribute Coding Catalogue (FACC) with extensions
- File formats used within CDB include:
  - OpenFlight* – Publicly published, privately controlled - Presagis, allows extension [13]
  - SHAPEFILE – Publicly published, privately controlled - Esri, no extension [14]
  - JPEG – Publicly published, publicly defined, no extension [15]
  - XML – Publicly published, publicly defined, allows extension [16]

* Proposal to make an OGC standard in progress

# SISO RIEDP

- Provides “the required information for identifying and describing specific instances and/or abstracted types of environmental features that, along with their specific attributes, value ranges, and metadata, will be utilized in environmental data products.”
- Promoted by Sogitec and developed within SISO RIEDP Product Development Group (PDG)
- Developed in an open committee with member consensus
- Actively in development
- Data organization is defined by specification
  - Identified based-on well define folder names and file names
  - Augmented with metadata within file formats and external files
  - Based on existing “well known” industry formats
  - Data labeling using SEDRIS Environmental Data Coding Specification (EDCS) with extensions
- File formats used within RIEDP include:
  - OpenFlight – Publicly published, privately controlled - Presagis, allows extension
  - SHAPEFILE – Publicly published, privately controlled - Esri, no extension
  - JPEG – Publicly published, publicly defined, no extension
  - XML – Publicly published, publicly defined, allows extension
  - GeoTIFF – Publicly published, publicly defined - OGC, no extension [17]
  - Portable Network Graphics (PNG) – Publicly published, publicly defined - World Wide Web Consortium (W3C), no extension [18]

# OGC 3DTiles

- Originally developed by Analytical Graphics, Inc. (AGI)
- Motivation was to have an open source worldwide streaming terrain geospatial data definition.
- AGI spun out Cesium as a separate company with 3DTiles support as a product
- Cesium offered 3DTiles to OGC as a community standard in 2018, where it was accepted
- Maintained by an online community and presented to OGC at logical intervals for OGC update acceptance
- Data organization is defined by metadata
  - Organization defined in the file metadata
  - Built on JSON and glTF industry formats
  - Data labeling is user defined
- File formats used within 3DTiles include:
  - JSON – Publicly published, publicly defined - International Organization for Standardization (ISO) and the (International Electrotechnical Commission (IEC), allows extension
  - JPEG – Publicly published, publicly defined, no extension
  - glTF – Publicly published, publicly defined – Khronos Group, allows extension

# WFF (3DTiles with extensions)

- WFF was coined in the STE request for solution. And adopted by the OWT project
- OGC 3DTiles 1.0 was selected based on the US Army's desire to have an all-inclusive worldwide streaming terrain geospatial data definition and the formats' ability to efficiently represent a 3D polygon mesh
- OWT collaborating in the 3DTiles online process to expand the standard to support the STE OWT objectives
- Data organization is defined by metadata
  - Organization defined in the file metadata
  - Built on JSON, glTF, and GeoJSON industry formats
  - Data labeling is Ground-Warfighter Geospatial Data Model (GGDM) with extensions
- File formats are:
  - JSON – Publicly published, publicly defined - ISO/IEC, allows extension
  - JPEG – Publicly published, publicly defined, no extension
  - glTF – Publicly published, publicly defined – Khronos Group, allows extension
  - GeoJSON – Publicly published, publicly defined - Internet Engineering Task Force (IETF), allows extension

# OWT's WFF Advantages

- WFF provides a human readable and computer parsable metadata organization
  - verses relying on file and folder names
- WFF represents the "world" in a 3D polygon mesh providing an efficient unambiguous complex geometric form,
  - compared to the uncertain and top-down raster data
- WFF has a universal, well-define level of detail (LOD) scheme,
  - verses using independent LOD definitions
- WFF has metadata for both the GIS data and the 3D polygon mesh, at all levels of the data organization
  - A challenge for runtime formats
- WFF tiling scheme is indexed for rapid access
  - verses reading folders and files
- WFF is streamable for managing network load and local storage
  - much harder with folders and files
- No polar singularities, tiles are generally the same size worldwide
  - variable sized tiles are typical in other stsndards

# Future Development Activities

- The OWT program continues to mature and extend the WFF to support the TSS/TMT and RVCT requirements. Efforts are underway to:
  - Extend the glTF lights definition to support the full range color, intensity, periodicity, directionality, and controls of lights, to include support for airport lighting
  - Extend the 3DTiles definition to support insets with variable resolution, to include indicators for tile level searches
  - Add support for positional uncertainty metrics, to include global and local uncertainty
  - Develop methods and standards to reduce excessive file counts
  - Formalize the archival format for group content
  - Expand coordinate systems support for custom exports
  - Add Map Vector Tile Format for map scales and rapid rendering
  - Expand glTF to support 3D Model, cultural and vehicle models
    - Geolocation
    - Articulations
    - Damage States
    - Animations
    - Seasons
- The OWT program is on track to complete format updates by September 2022

# Initial Lessons Learned

- Selecting format before requirements analysis complete brings technical, cost and schedule risk
  - Some shortfalls in 3DTiles – example vector data to the 3DTiles
  - Perhaps another format would have been selected
- Developing content requirements without defined runtime system capabilities brings solution risk
  - OWT WFF is vendor and solution independent, but
  - Understanding runtime systems requirements early in development would reduce rework
- Building content at a global scale brings unexpected system constraints
  - Limitations were quickly encountered
  - Testing at scale earlier in the development would have reduced redesign
- Unplanned delivery commitments required temporary solutions and unplanned Unplanned delivery commitments required temporary solutions and unplanned rework
  - Interest by other organizations (outside of STE) requesting OWT content in the WFF resulted in temporary format decisions
  - Defining format before beginning deliveries would reduce rework
- Balancing the desires of a prototype program with the desires of a production capability is challenging
  - US Army is hoping that the prototype solution can transition directly to a production contract
  - Limitations of certain collection concepts have not resulted in the desire capability
  - More work is required to complete the vision

# Questions

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MAXAR.COM