Community Standard Justification: 22-006

TITLE: 3D Tiles 1.1 Community Standard Justification

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1. Introduction

This document presents the justification for submission of the next revision to the OGC 3D Tiles Community Standard for consideration by the OGC Technical Committee (TC). This justification forms the basis for TC review and vote to approve initiation of a Work Item to update the OGC 3D Tiles Community Standard to version 1.1.

The submitters agree to abide by the TC Policies and Procedures and OGC Intellectual Property Rights Policy (http://www.opengeospatial.org/ogc/policies) during the processing of this submission.

Once approved, the Community standard Work Item defined by this document is valid for six (6) months.

2. Overview of proposed submission

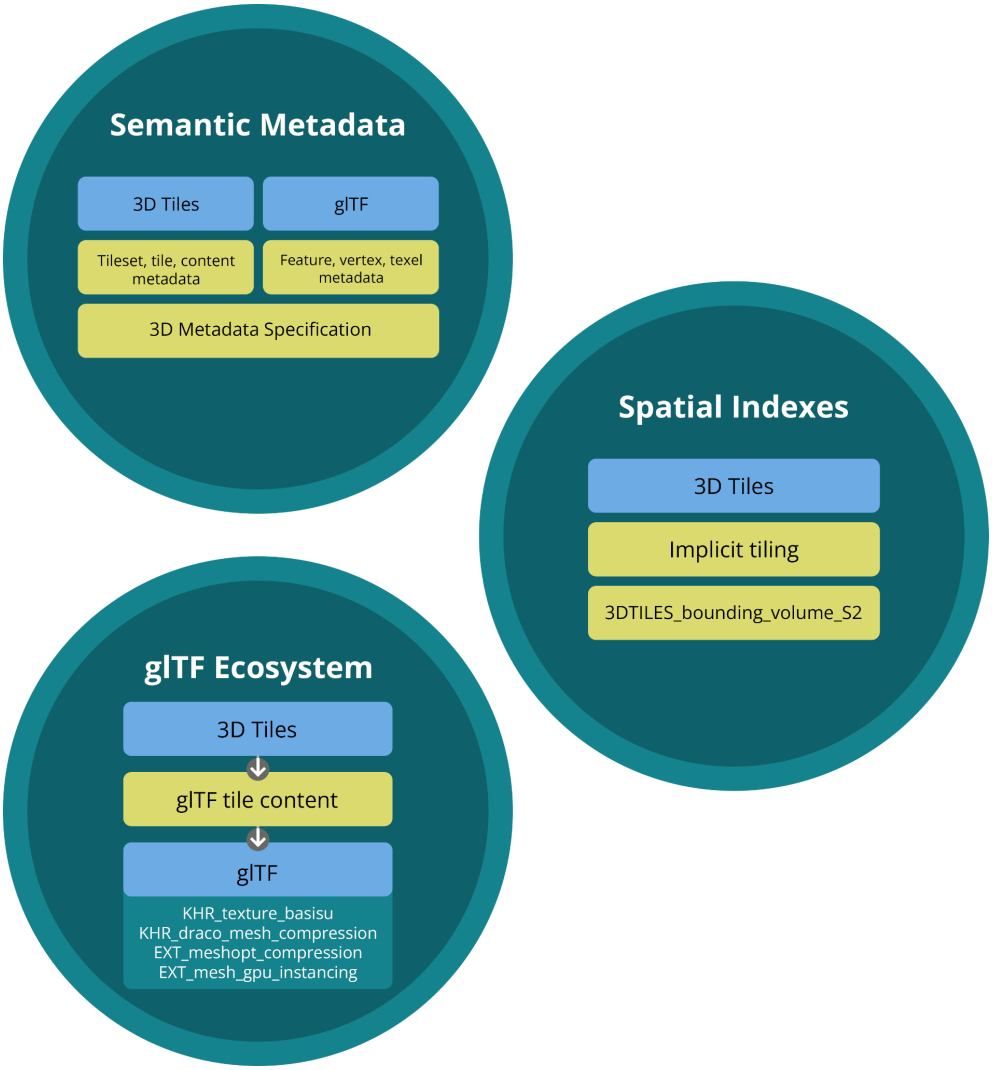
3D Tiles 1.0 is an OGC Community Standard for sharing, visualizing, fusing, and interacting with massive heterogenous 3D geospatial content across desktop, web, and mobile applications.

3D Tiles 1.1 is a proposed revision to the 3D Tiles community standard designed for streaming high-resolution semantically-rich 3D geospatial data to the metaverse. 3D Tiles 1.1 promotes several 3D Tiles 1.0 extensions to core and introduces new glTF extensions for fine-grained metadata storage.

The primary enhancements proposed for OGC 3D Tiles 1.1 include:

- Semantic metadata at multiple granularities
- Implicit tiling for improved analytics and random access to tiles
- Multiple contents per tile to support layering and content groupings

- Direct references to glTF content for better integration with the glTF ecosystem

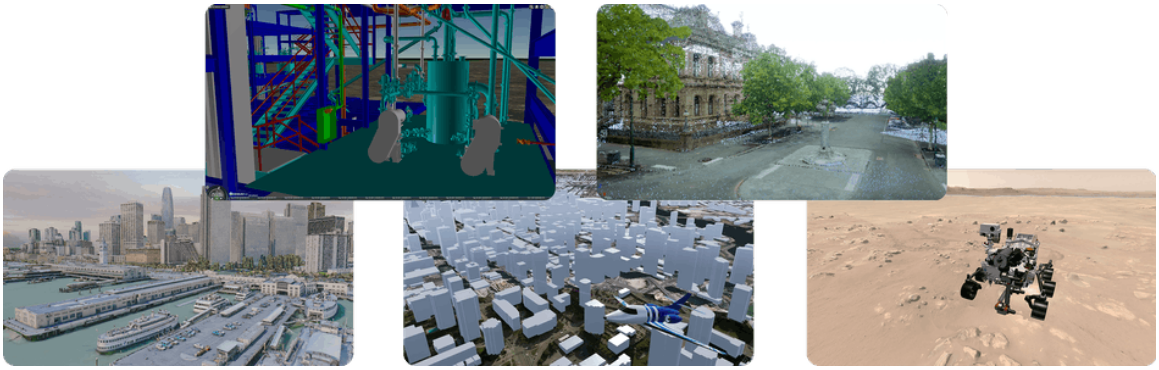


3D Tiles 1.1 is backwards compatible with 3D Tiles 1.0 — aside from version number itself, valid 1.0 tilesets are also valid 1.1 tilesets.

3D Tiles 1.1 is expected to be finalized in May 2022. Reference implementers are committed to updating their implementations with the final release of the specification. OGC member review of the specification after approval of the Justification document will be valuable in finalization.

Background

3D Tiles was announced at SIGGRAPH in August 2015. It was published as an OGC community standard on January 31, 2019. Since then we have been inspired by how the community has built apps, exporters, APIs, and engines with 3D Tiles to grow an open and interoperable 3D geospatial ecosystem.



Power plant CAD model from Bentley Systems in CesiumJS, point cloud from Government of Victoria in Unreal Engine, San Francisco photogrammetry model from Aerometrex in O3DE, OSM buildings in STK, NASA Perseverance Rover at Jezero Crater in Three.js

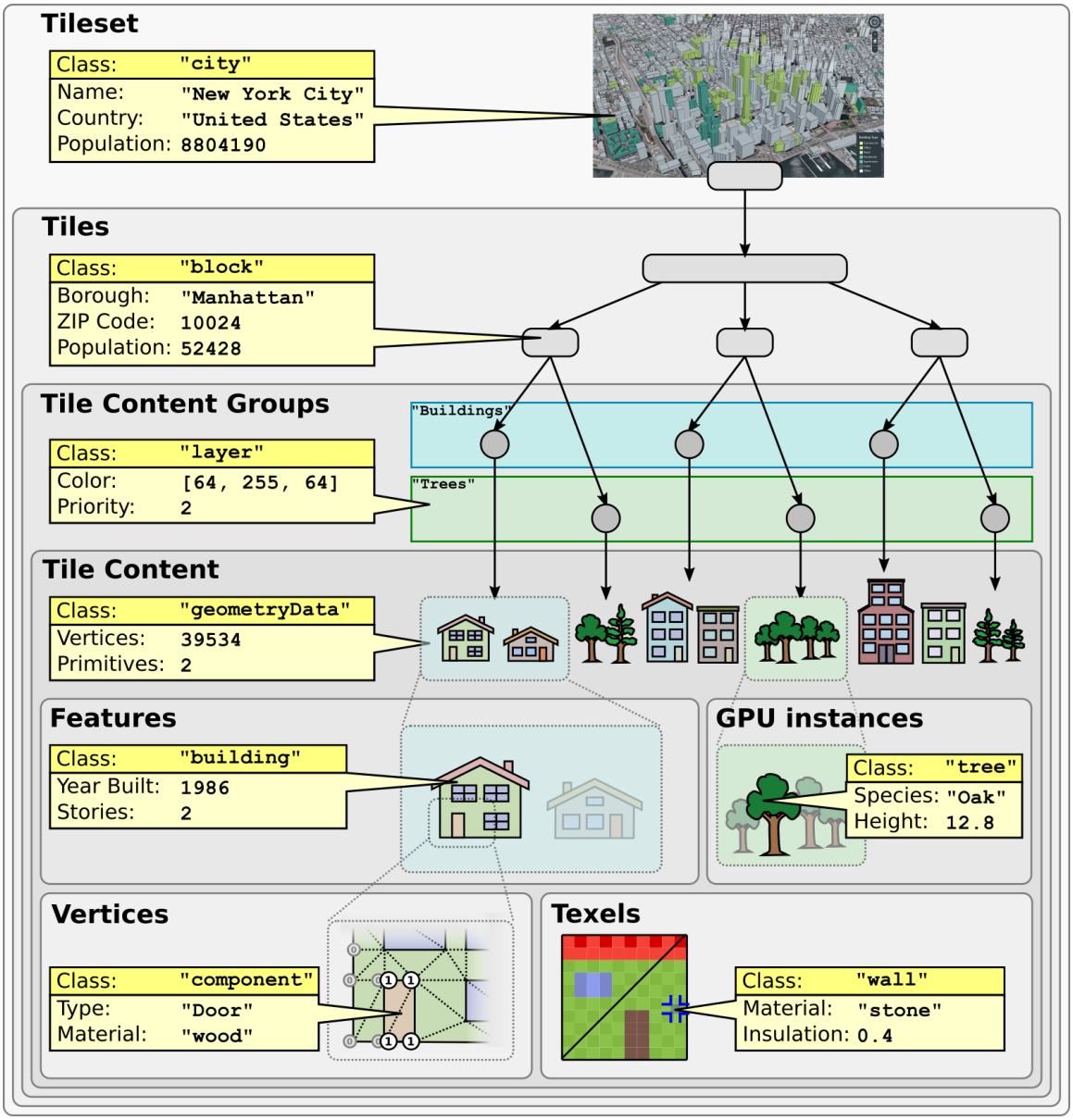
This collective experience building with 3D Tiles, combined with the continued growth of 3D geospatial data availability, especially semantic metadata, and increasing user interest in digital twins and the metaverse has led to this revision of the 3D Tiles specification.

In developing 3D Tiles 1.1, we collaborated closely with Maxar in support of the U.S. Army's One World Terrain (OWT) program. 3D Tiles 1.1 is the data standard used to store and deliver geospatial terrain data to the U.S. Army's Synthetic Training Environment (STE) Point of Need (PoN) training systems.

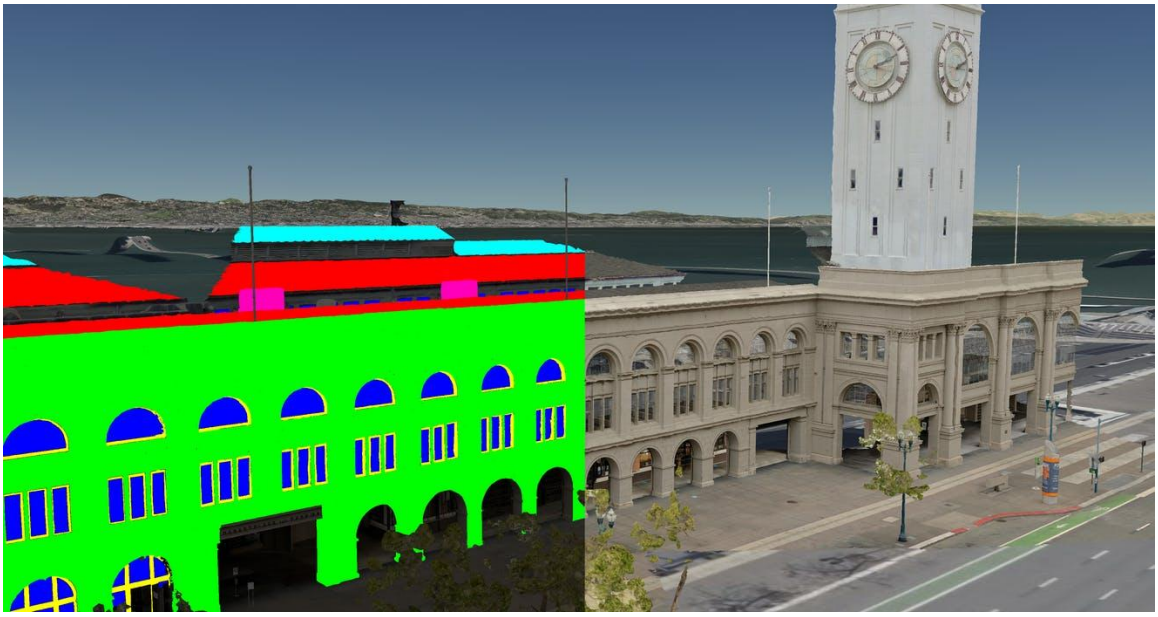
2.1 Semantic Metadata

In 3D Tiles 1.1, we placed a large emphasis on metadata due to its increasing availability and users' needs. Just as today's vehicle, sensor, compute, and photogrammetry trends have enabled us to capture the real world with ever-increasing geometry and texture resolution, today's AI algorithms are increasingly more semantically-rich metadata to augment 3D models.

Metadata in 3D Tiles gains more expressiveness and flexibility, with a well-defined type system, new encoding options (e.g. JSON or binary), and a range of granularity options. Metadata may be associated with high-level objects like tilesets, tiles, contents, or content groups, or with individual vertices and texels on glTF 2.0 geometry.



3D Tiles also provides a Semantic Reference, used to describe the semantic meanings of properties. Semantics may be general-purpose (e.g. ID, name, or description), related to 3D Tiles (e.g. bounding volumes and occlusion data), or extended and customized for other domains.



Street level photogrammetry of San Francisco Ferry Building from Aerometrex. Left: per-texel colors showing the feature classification, e.g., roof, sky roof, windows, window frames, and AC units . Right: classification is used to determine rendering material properties, e.g., make the windows translucent.

2.2 Implicit Tiling

3D Tiles 1.1 optimizes spatial subdivision, enabling fast spatial queries, faster analysis, and greater interoperability with GIS and simulation ecosystems.

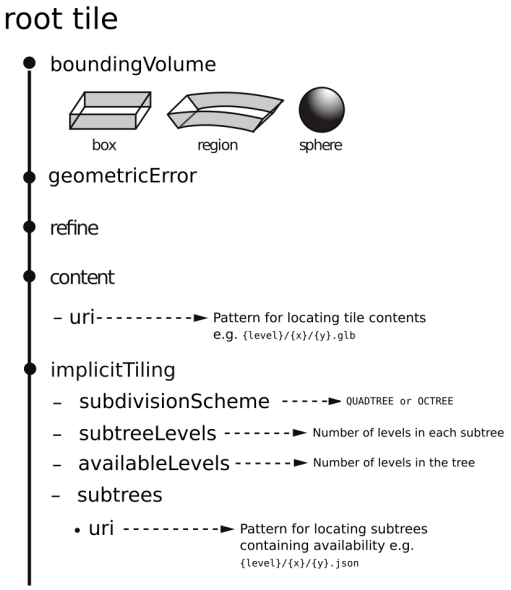
In 3D Tiles 1.0, spatial subdivision is explicitly defined in one or more tileset.json files defining the spatial data structure, i.e., each tile's bounding volume, content, and child tiles, recursively to the leaf tiles.

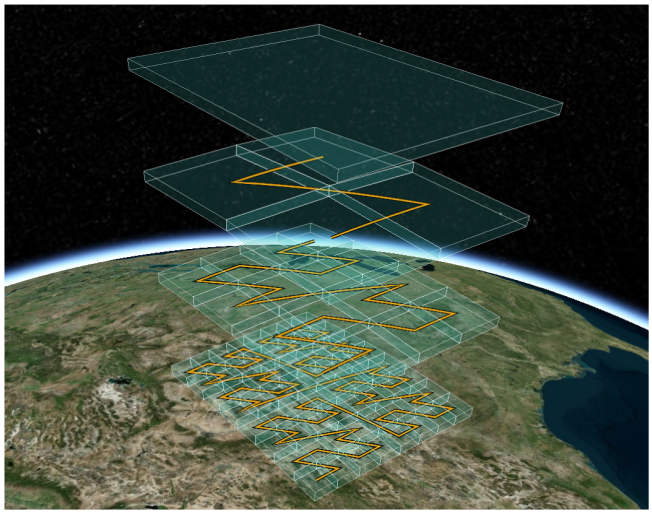
With 3D Tiles 1.1, implicit tiling introduces support for well-known spatial indexes in a 3D tileset without the need to explicitly list tile bounding volumes. Enabling random access to any tile, or any number of tiles needed to display or analyze a region, this enables optimizations for:

- Large-scale simulation of agents running on a single server or across multiple compute units where efficient k-nearest neighbors and range queries are beneficial
- Analytics based on ray tracing, ray marching, and spatial queries where a uniform spatial index enables efficiency gains
- Partial updates for when just a subset of a 3D tileset needs to be updated, such as a stockpile in a construction site, or a new building in a city model

Implicit tiling defines a concise representation of quadtrees and octrees. This regular pattern allows for random access of internal tiles in a potentially large tile hierarchy based on their tile

coordinates. In order to support sparse datasets, tile availability is partitioned into fixed-size subtrees. Subtrees may also store metadata for available tiles and content.





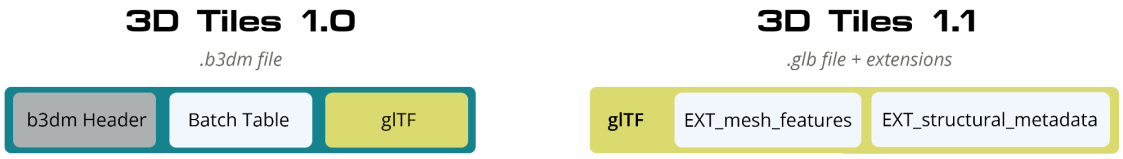
2.3 Multiple Contents

Multiple contents allows storing more than one content model per tile, and in effect, per single volume of space. Contents can be organized in various ways — e.g. as map layers or arbitrary groupings — which becomes particularly useful when combined with content group metadata.

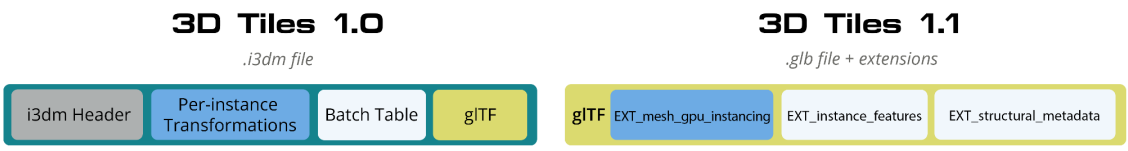
2.4 glTF Content

In 3D Tiles 1.1, a tile may now directly reference a .gltf or .glb file instead of referencing a .b3dm or .i3dm with embedded glTF.

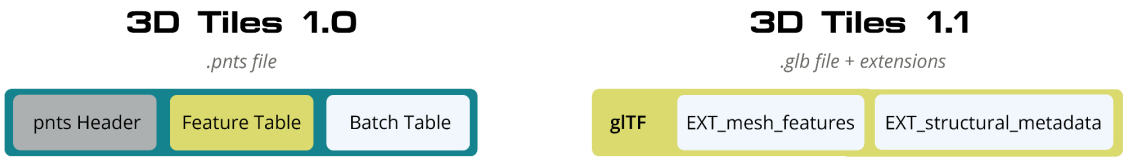
This will enable the 3D Tiles communities and glTF communities to more easily benefit from each other's work. The 3D Tiles community can use glTF tools such as validators, converters, pipelines, modeling tools, and runtime loaders; and the glTF community benefits from contributions to these tools and new glTF tools.



Left: 3D Tiles 1.0 with .b3dm to reference glTF. Right: 3D Tiles 1.1 with direct glTF reference using EXT_mesh_features and EXT_structural_metadata to replace the Batch Table for storing metadata.



Left: 3D Tiles 1.0 with .i3dm for instancing glTF. Right: 3D Tiles 1.1 with direct glTF reference using EXT_mesh_gpu_instancing for instancing and EXT_instance_features and EXT_structural_metadata to replace the Batch Table for storing metadata.



In 3D Tiles 1.0, point clouds were stored in a .pnts binary file, a feature table for point geometry attributes, a batch table for metadata, and Draco for compression. 3D Tiles 1.1 now leverages the glTF ecosystem for point clouds: point geometry is now stored in glTF using EXT_mesh_features to identify point features and EXT_structural_metadata to store metadata.

3D Tiles 1.1 will continue to use glTF extensions for geometry compression such as Draco and Meshopt, and texture compression such as KTX 2.0, as well as PBR Next materials.

Point cloud compression

The tables below show the file sizes and loading times in CesiumJS for a medium-size point cloud with different compression methods.

- # points: 313,605,932
- Properties: position, color
- Compression Error: 0.01 meters
- Network speed (throttled): 50 Mbps
- Screen space error: 4px

Data: Aalto University with support from City of Helsinki https://zenodo.org/record/5578198#.YjoTWBNKiu4

File Size	
LAS (point record format 3)	12.3 GiB
pnts	4.38 GiB
glb	4.68 GiB
pnts + draco	1.19 GiB
glb + meshopt	1.01 GiB
pnts + gzip	3.72 GiB
glb + gzip	3.67 GiB
pnts + draco + gzip	0.85 GiB
glb + meshopt + gzip	0.86 GiB

Load Time	
pnts	33.3 seconds
pnts + draco	9.25 seconds

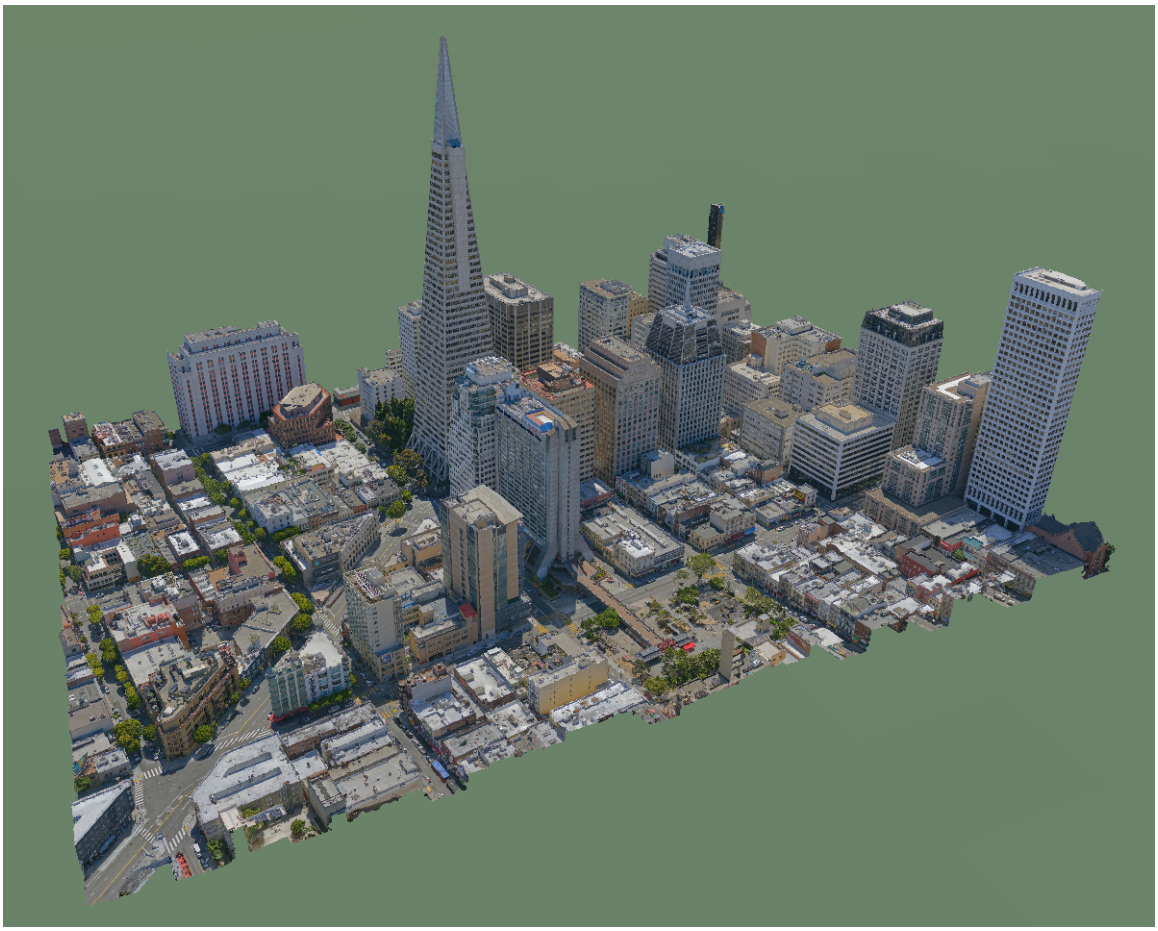
glb + meshopt	9.46 seconds (*)

* Experimental meshopt decoder doesn't use Web Workers yet - expecting to see even better decode performance

Mesh and texture compression

The tables below show the file sizes, loading times, and GPU memory usage in CesiumJS for a photogrammetry tileset with different compression methods: Draco and Meshopt geometry compression and KTX 2.0/Basis with ETC1S texture compression mode.

- Geometry compression error: 0.01 meters
- JPEG quality: 80 (out of 100) (with stb_image)
- Texture compression quality: 192 (out of 255) (with basis_universal)
- Screen space error: 4px
- GPU compressed texture format: DXT1



Data: Aerometrex - photogrammetry model of downtown San Francisco

File Size	
glb + png	3.70 GiB
glb + jpeg	1.01 GiB
glb + ktx2/basis/etc1s	1.15 GiB
glb + jpeg + draco	0.46 GiB
glb + jpeg + meshopt	0.55 GiB
glb + ktx2/basis/etc1s + meshopt	0.68 GiB
glb + png + gzip	3.45 GiB
glb + jpeg + gzip	0.82 GiB
glb + ktx2/basis/etc1s + gzip	0.95 GiB
glb + jpeg + draco + gzip	0.45 GiB
glb + jpeg + meshopt + gzip	0.50 GiB
glb + ktx2/basis/etc1s + meshopt + gzip	0.64 GiB

Load Time (local disk, throttled 50Mbps)	
glb + jpeg	24.2 seconds
glb + ktx2/basis/etc1s	23.5 seconds
glb + jpeg + draco	11.15 seconds
glb + jpeg + meshopt	12.95 seconds
glb + ktx2/basis/etc1s + meshopt	12.61 seconds

Load Time (local disk, no throttling)	
glb + jpeg	5.16 seconds
glb + ktx2/basis/etc1s	4.65 seconds
glb + jpeg + draco	5.69 seconds
glb + jpeg + meshopt	5.07 seconds
glb + ktx2/basis/etc1s + meshopt	4.21 seconds

Memory Usage	Texture Memory (GPU)	Geometry Memory (GPU)
glb + jpeg	834 MB	108 MB
glb + ktx2/basis/etc1s	105 MB	108 MB
glb + jpeg + draco	834 MB	72 MB
glb + jpeg + meshopt	834 MB	72 MB
glb + ktx2/basis/etc1s + meshopt	105 MB	72 MB

3. Relationship to other OGC standards

3D Tiles does not depend on any OGC standards.

Currently, no OGC standards normatively reference 3D Tiles.

4. Alignment with OGC Standards Baseline

Examples of 3D Tiles interoperability within the OGC ecosystem:

OGC API - 3D GeoVolumes provides an API for organizing access to a variety of 2D / 3D content, and informally references 3D Tiles as a possible content type. This capability was demonstrated in the OGC 3D Data Container and Tiles API Pilot. The GeoVolumes SWG is exploring tile coordinate-based content retrieval and harmonization with 3D Tiles 1.1 implicit tiling.

vis.gl includes an open-source command-line utility that converts between OGC I3S 1.2 Community Standard and OGC 3D Tiles 1.0 Community Standard.
Github link: https://github.com/visgl/loaders.gl/tree/master/modules/tile-converter

Cesium provides an open source CDB OGC 1.2 to 3D Tiles 1.1 converter. The CDB standard defines an open format for the storage, access, and modification of a synthetic environment database. When converted to 3D Tiles the data is optimized for streaming and runtime performance, including offline-batching of GSModels and GPU instancing for GTModels, leveraging glTF extensions such as EXT_mesh_gpu_instancing.
Github link: https://github.com/CesiumGS/cdb-to-3dtiles/pull/58

3D Tiles 1.1 can be used as an efficient format for streaming massive city datasets, including semantic metadata, originally stored in CityGML.

Refer to the original OGC 3D Tiles Community Standard Work Item Justification document [OGC 16-123] https://portal.ogc.org/files/?artifact_id=70040&version=1 for additional examples of 3D Tiles interoperability within the OGC ecosystem.

5. Evidence of implementation

The following implementations use the proposed Community standard.

1. Implementation name: Maxar
Date of most recent version: Ongoing as the 3D Tiles 1.1 spec finalizes
Implementation description: Pipeline to convert high-resolution 3D surface model to 3D Tiles 1.1 in support of the U.S. Army's One World Terrain (OWT) program. The delivery format extends 3D Tiles 1.1 with domain-specific semantics such as GGDM. Visualization and analysis support in Vricon Explorer. All major 3D Tiles 1.1 updates are supported including semantic metadata at tileset, tile, group, vertex, and texel granularity, implicit tiling, glTF content, and S2 bounding volumes extension.

Implementation URL:

https://www.maxar.com/products/vricon-explorer
https://www.maxar.com/products/precision3d-data-suite
https://demos.cesium.com/owt-uncertainty
https://demos.cesium.com/owt-globe

Is implementation complete? ☒ **Yes** ☐ **No**

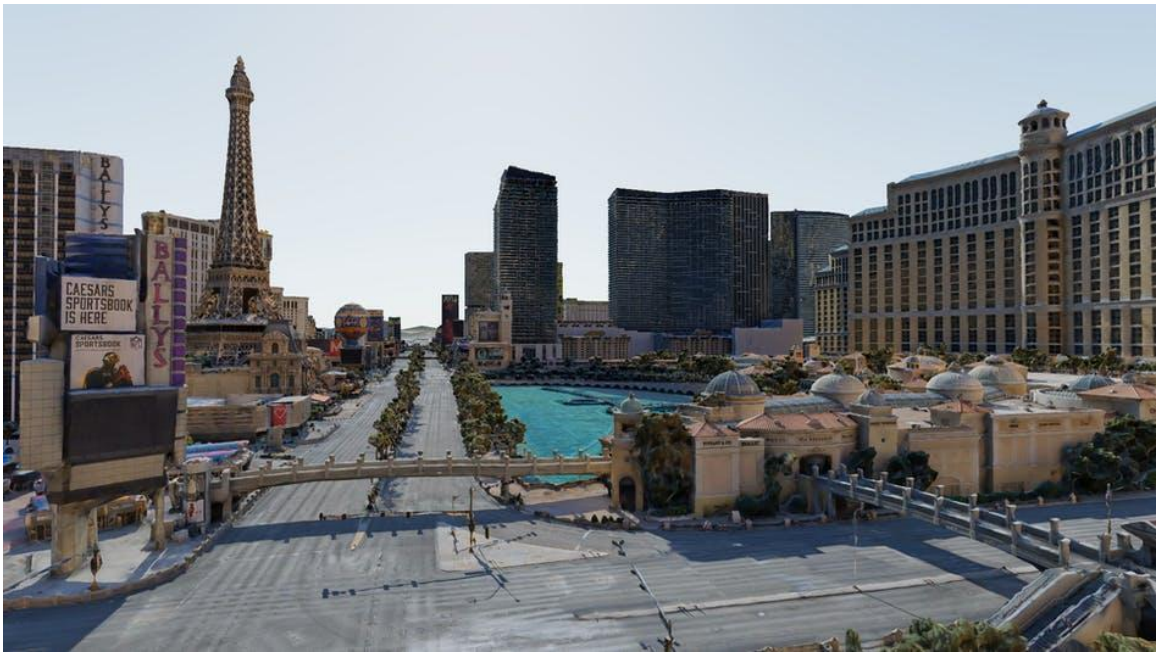
2. Implementation name: CesiumJS
Date of most recent version: Ongoing as the 3D Tiles 1.1 spec finalizes
Implementation description: Open-source reference implementation with support for all 3D Tiles 1.1 capabilities. Experimental features expected to stabilize mid 2022.

San Francisco Ferry Building from Aerometrex with per-texel feature classification.

Implementation URL:
https://github.com/CesiumGS/cesium
https://sandcastle.cesium.com/?label=3D%20Tiles%20Next
https://demos.cesium.com/ferry-building
https://demos.cesium.com/cdb-yemen

Is implementation complete? ☒ Yes ☐ No

3. Implementation name: Cesium Native / Cesium for Unreal / Cesium for O3DE
Date of most recent version: Ongoing as the 3D Tiles 1.1 spec finalizes
Implementation description: Open-source C++ streaming library and serializers in Cesium Native. Open-source renderers in Cesium for Unreal and Cesium for O3DE. Experimental features expected to stabilize mid 2022.



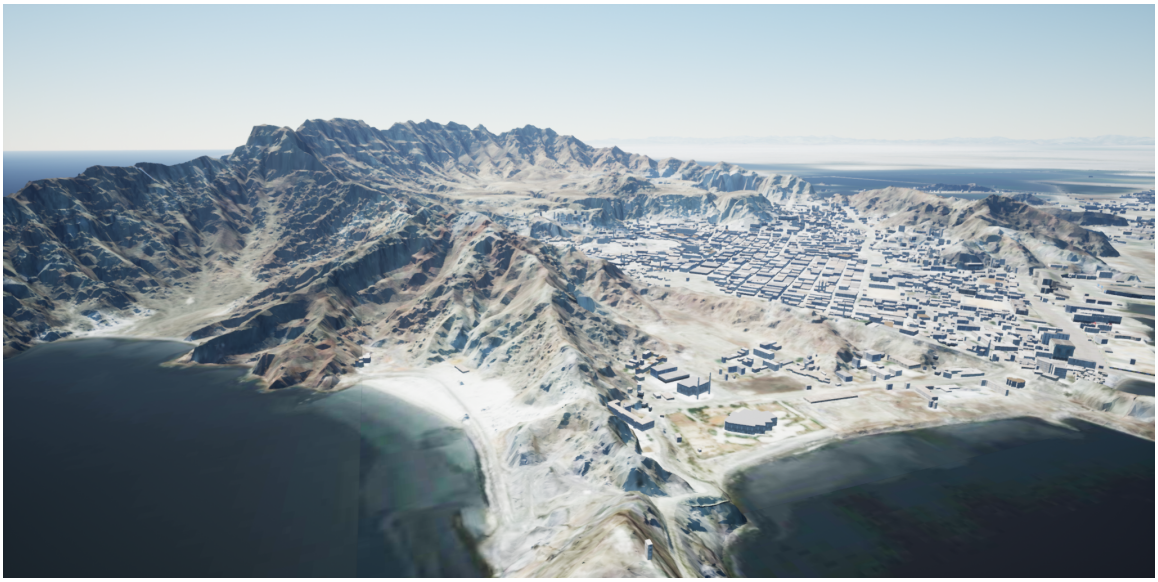
Screenshot of the Las Vegas Strip created with Cesium for O3DE. Las Vegas, NV, USA Data provided by Aerometrex.

Implementation URL:
https://github.com/CesiumGS/cesium-native
https://github.com/CesiumGS/cesium-unreal
https://github.com/CesiumGS/cesium-o3de

Is implementation complete? ☐ **Yes** ☒ **No**

Implicit tiling, glTF content, partial support for metadata

4. Implementation name: Cesium 3D Tiling Pipelines
Date of most recent version: Ongoing as the 3D Tiles 1.1 spec finalizes
Implementation description: Open-source tiling pipeline to convert CDB to 3D Tiles 1.1. Closed-source tiling pipelines to convert digital elevation models, massive photogrammetry models, point clouds, and CityGML to 3D Tiles 1.1. Open-source 3D Tiles 1.1 samples in progress.



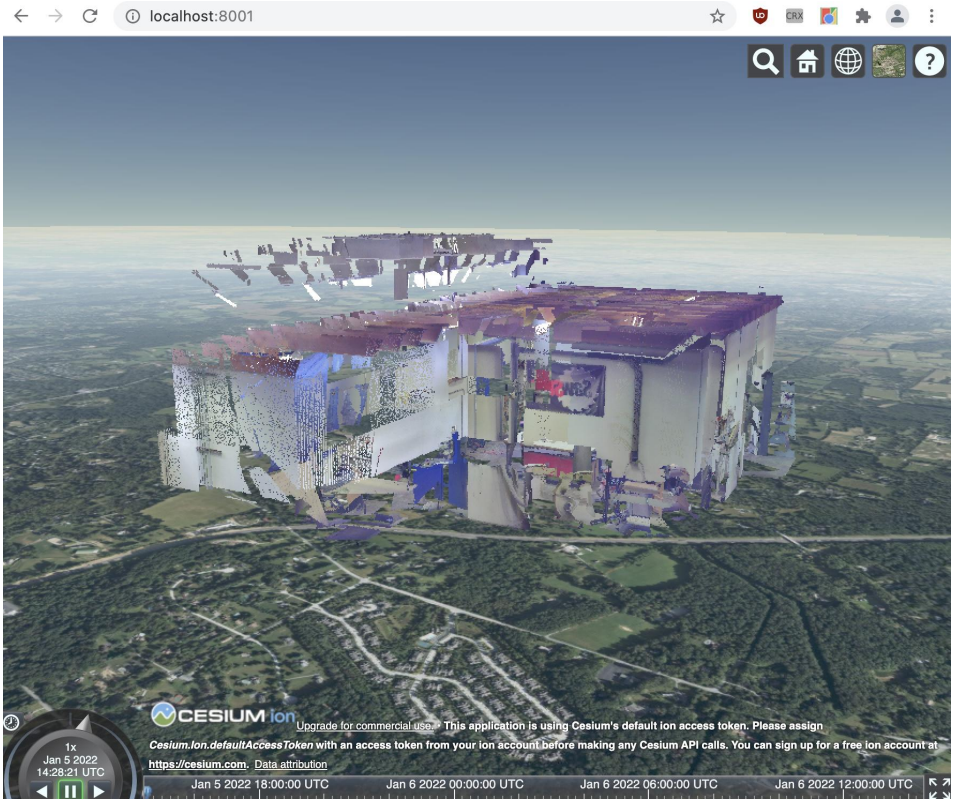
Yemen dataset with terrain, imagery, and 3D buildings converted from CDB to 3D Tiles and visualized in Cesium for Unreal.

Implementation URL:
https://github.com/CesiumGS/cdb-to-3dtiles/pull/58
https://github.com/CesiumGS/3d-tiles-samples#3d-tiles-next

Is implementation complete? ☐ **Yes** ☒ **No**
If not, what portions of the proposed Community standard are implemented?

Implicit tiling, glTF content, partial support for metadata

5. Implementation name: Autodesk
Date of most recent version: Ongoing as the 3D Tiles 1.1 spec finalizes
Implementation description: glTF profile for an open format point-cloud standard, leveraging glTF and 3D Tiles 1.1. Closed source pipeline with tileset visualized in ThreeJS and CesiumJS.



Implementation URL: https://github.com/wallabyway/minimal-pointcloud-gltf
Is implementation complete? ☐ **Yes** ☒ **No**

If not, what portions of the proposed Community standard are implemented?

Implicit tiling and glTF content

6. Implementation name: Vis.gl

Date of most recent version: November 2021

Implementation description: Vis.gl is a suite of composable, interoperable open source geospatial visualization frameworks centered around deck.gl. Support for glTF content and implicit tiling were added in November 2021.

Implementation URL: https://github.com/visgl/loaders.gl/tree/master/modules/3d-tiles

Is implementation complete? ☐ **Yes** ☒ **No**

If not, what portions of the proposed Community standard are implemented?

Implicit tiling and glTF content

6. Public availability

Is the proposed Community standard currently publicly available? ☒ **Yes** ☐ **No**

URL: https://github.com/CesiumGS/3d-tiles/tree/draft-1.1 (see pull request here)

7. Supporting member(s)

- Analytical Graphics Inc., an Ansys Company
- Autodesk, Inc.
- Bentley Systems, Inc.
- Blackshark.ai

- Botts Innovative Research, Inc.
- Camptocamp
- Cesium GS, Inc.
- Epic Games, Inc.
- Geoscience Australia
- Google LLC
- Hexagon AB
- Hochschule für Technik Stuttgart
- Iron EagleX, Inc.
- Maxar Technologies, Inc.
- Microsoft Corporation
- Safe Software, Inc.
- SimBlocks LLC
- The Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Trimble, Inc.
- U.S. Army Geospatial Center (AGC)
- U.S. National Geospatial-Intelligence Agency (NGA)
- Virtual City Systems GmbH

8. Intellectual property rights

Will the contributor retain intellectual property rights? ☒ **Yes** ☐ **No**

If yes, the contributor will be required to work with OGC staff to properly attribute the submitter's intellectual property rights.

If no, the contributor will assign intellectual property rights to the OGC.