CESIUM FOR UNREAL

Cesium for Unreal: WGS84 precision at global scale, now for game engines

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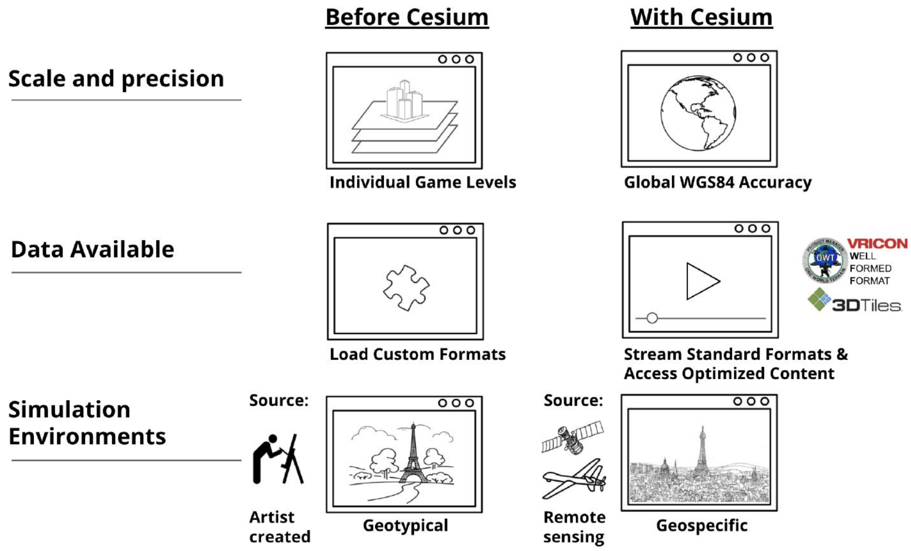
Abstract: Cesium for Unreal Engine takes game engines from level-based simulations to a precise WGS84 globe and provides a way for users to quickly incorporate data from supported formats, optimizing content for runtime performance at the point of need. The approach provides a high degree of precision at all distances. By incorporating Cesium ion components, users can transform and optimize all kinds of additional 3D data and fuse them into the simulation environment, and add curated global datasets as needed. The global scale of Cesium's visualizations will make simulations that cover large areas of the earth possible, and the underlying technology makes connecting to operationally-focused systems like IVAS and ATAK much more direct.

WGS84 precision at global scale, now for game engines

Cesium is leading a revolution in game engines for modeling and simulation with its introduction of Cesium for Unreal Engine, a plugin that brings the accuracy of the WGS84 standard to the performance and visual realism of game engines. Combined with Cesium ion components, game engine simulations now have the ability to bring in data from many sources, optimized for exceptional runtime performance at a global scale.

By bringing 10 years of market-leading geospatial visualization to modeling and simulation, Cesium is transforming game engines for training. Cesium for Unreal Engine takes game engines from level-based simulations where environments are rectangular sections of a location, to incorporating everything into a precise WGS84 globe.

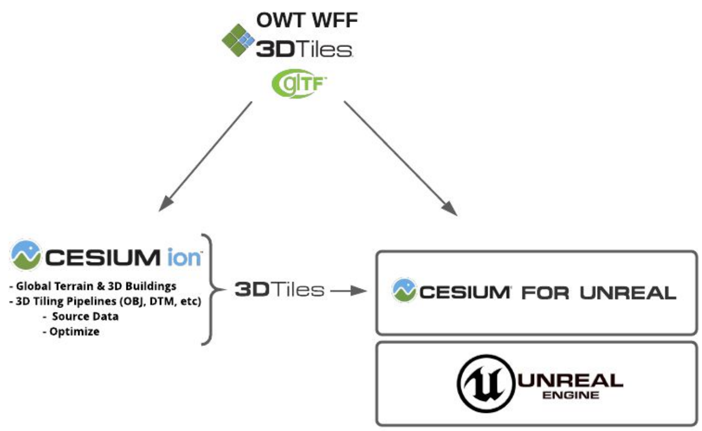


In addition to precision, Cesium brings in and optimizes more kinds of data for more accurate and current simulation environments.

Users are able to render the One World Terrain Well Formed Format and other supported formats, as well as optimize content for runtime performance at the point of need. And with Cesium for Unreal Engine, geospecific simulation environments become the norm, where remote sensing capabilities gather and construct environments that accurately reflect the real world as opposed to geotypical environments that rely on artists' depictions.

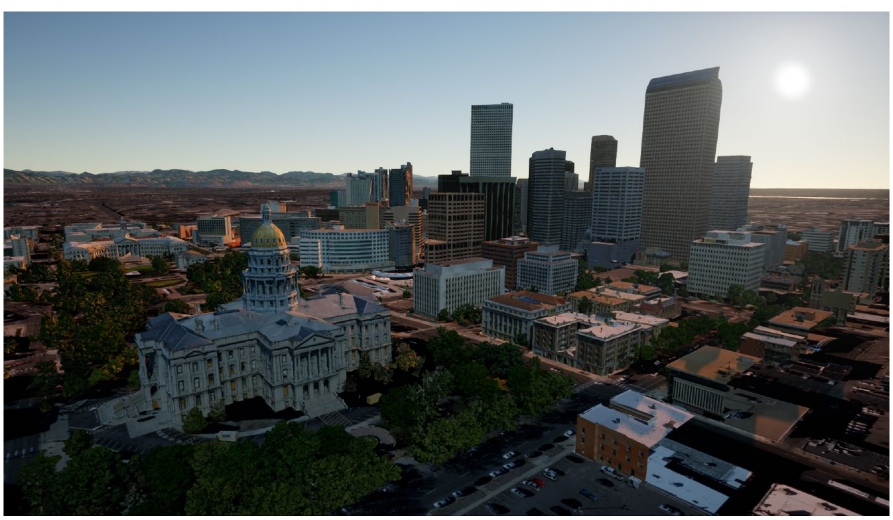
Cesium ensures high-precision rendering and analytics in a full-scale WGS84 globe using a 64-bit floating-point rendering technique. Cesium's origins in aerospace required tracking satellites with the same precision required for taking measurements on the ground, resulting in precise rendering on land, sea, air, and space. Massive heterogenous geospatial data is represented as hierarchical level-of-detail structure of tiles, where each point on the virtual globe has a corresponding maximum possible error in relation to the real world, with geometry closer to the camera rendered with high detail and smaller error than objects further away. This allows users to compute, analyze, and simulate environments in Cesium that will always have a known error tolerance (See Appendices A and B).

Cesium and Epic Games are releasing this capability as Cesium continues its work with Maxar to build Army One World Terrain's Well Formed Format for the Synthetic Training Environment (STE). Built on 3D Tiles, the Well Formed Format redefines simulation environments, using photogrammetry and algorithms applied to satellite and drone imagery to create highly accurate, 3D representations of the earth for training systems (See Appendix B). Warfighters will be able to train on precise, virtual reconstructions of the world, enhancing training value at every level.



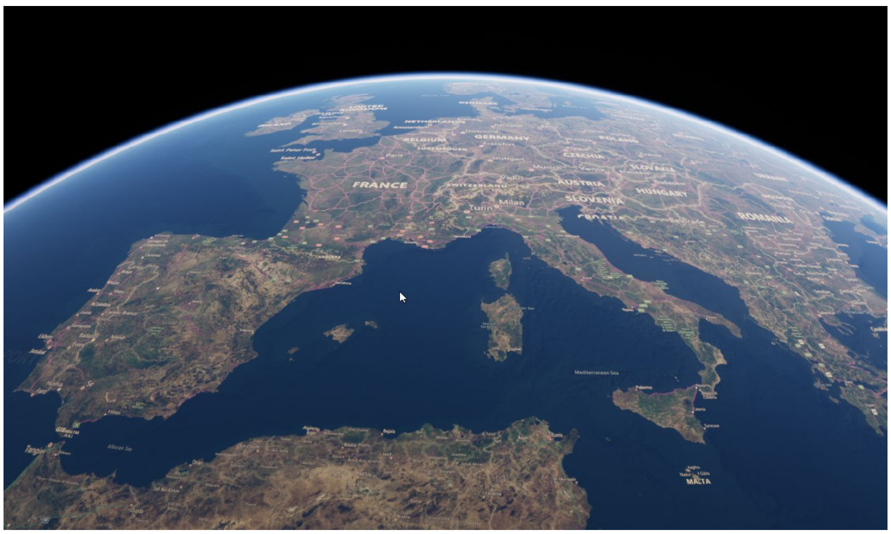
Cesium ion components integrate and optimize additional geospatial data

Users of Cesium for Unreal Engine also have the opportunity to add significantly greater value to their simulations by applying Cesium ion components on-premise. Built to fuse heterogeneous data, Cesium's 3D Tiling Pipeline transforms and optimizes all kinds of additional 3D data (including 3D models, point clouds, photogrammetry, terrain and imagery) into 3D Tiles, making it easy to update and build upon your simulation with new information and provide a high performing visualization even at the tactical edge. Additional Cesium ion components include Cesium World Terrain, a global dataset that includes 3D terrain as well as Sentinel-2 imagery, and Cesium OSM Buildings, a crowdsourced, continuously growing global dataset of over 350 million buildings with metadata.



Colorado State Capitol, Denver: Unreal Engine's visual realism takes on new applicability with geospatial precision and global scale

Going forward, Cesium for Unreal Engine will unlock a number of key developments for both the modeling and simulation community and operational users of geospatial data. For live, virtual and constructive (LVC) simulations, the global scale of Cesium's visualizations will make simulations that cover large areas of the earth possible, allowing for realistic and large-scale representations of Joint All Domain Operations (JADO). For currently fielded and future soldier visualization capabilities such as Android Tactical Assault Kits (ATAK) and the Integrated Visual Augmentation System (IVAS) the underlying technology enabling Cesium for Unreal Engine opens opportunities to harmonize authoritative geospatial data formats like CDB and the OWT Well Formed Format with dynamically gathered high resolution insets for use in real-world operations.



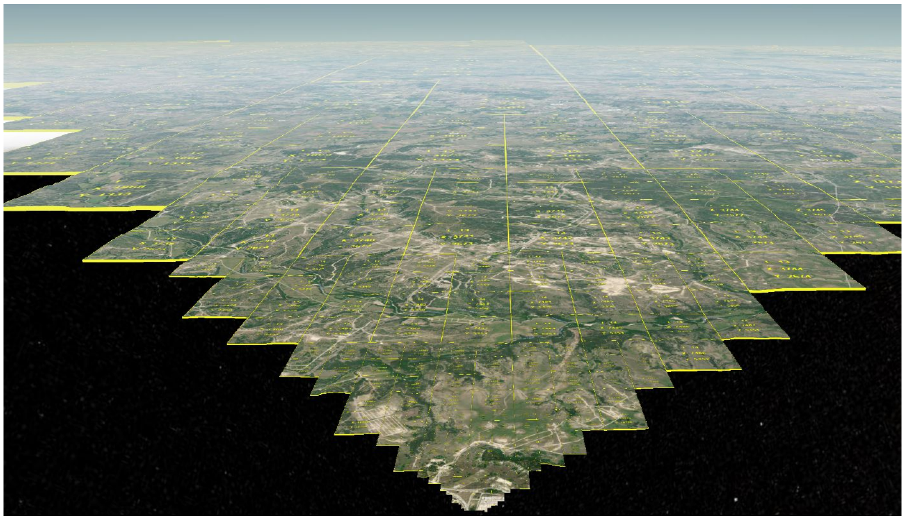
Cesium's 3D Tiles makes scaling in and out of global locations smooth and realistic

The introduction of Cesium to Unreal Engine signals a convergence of valuable and plentiful operational, real-world data with the needs of a rapidly evolving modeling and simulation industry. What integrators and warfighters are able to achieve with this development will ensure that the landscape will never be the same.

To learn more, contact Brady Moore, Director of Mission Support at brady@cesium.com and visit https://cesium.com/blog/2020/06/04/cesium-for-unreal-engine/. Prepare by getting access to the Cesium ion platform at https://cesium.com/cesium-ion/. Users who sign up for a community account with .mil and .gov addresses get access to 30 global locations of Vricon Surface Mesh for visualization and analysis.

Appendix A: Precision in Cesium for Unreal Engine

- Due to the 3D Tiles level-of-detail algorithm, vertex precision error when larger tiles are rendered is invisible because it is smaller than a pixel on the screen.



A horizon view utilizes tiles of a wide range of sizes; here the smallest tiles shown have a radius of about 25 meters while the largest have a radius of about 50 kilometers

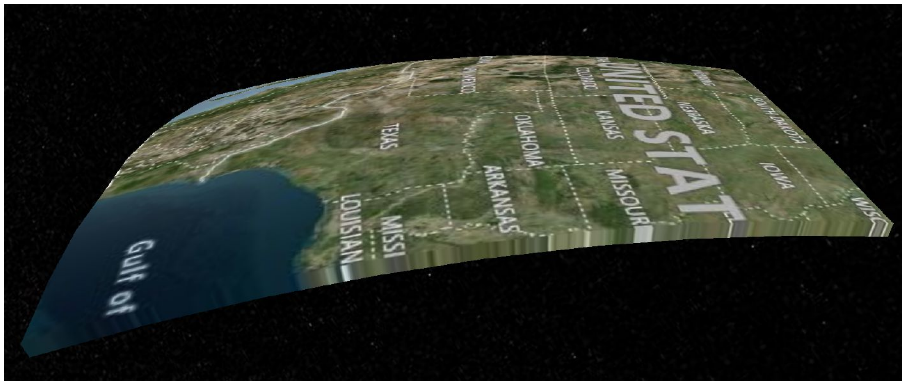
- Cesium-specific parts all use double-precision 64-bit floats.
- Cesium automatically keeps the Unreal world origin near the camera. Unreal's world origin is specified using 32-bit signed *integers* in centimeters, so it has exactly centimeter precision over its entire range.
- Unreal Engine 4 internally uses 32-bit floats single-precision for vertex positions *and* transformation matrices.
- Maximum allowed distance from origin to camera before the origin is moved is configurable. The default is 100 meters.
- The maximum distance acts as a clamp on the precision:
  - The precision is unaffected for tiles that are large relative to the max distance.
  - Even with arbitrarily small tiles, worst-case precision is limited by the distance.

Tile radius	Vertex precision with origin rebase every 100 meters (approx.)	Vertex precision with origin rebase every 10 meters (approx.)
< 1 meter	1 millimeter (1e-3 meters)	0.1 millimeter (1e-4 meters)
< 10 meters	1 millimeter (1e-3 meters)	0.1 millimeter (1e-4 meters)
< 100 meters	1 millimeter (1e-3 meters)	0.1 millimeter (1e-4 meters)
< 1 kilometer	1 millimeter (1e-3 meters)	1 millimeter (1e-3 meters)
< 10 kilometers	1 centimeter (1e-2 meters)	1 centimeter (1e-2 meters)
< 100 kilometers	0.1 meter (1e-1 meters)	0.1 meter (1e-1 meters)
< 1,000 kilometers	1 meter (1e0 meters)	1 meter (1e0 meters)
Entire Earth	10 meters (1e1 meters)	10 meters (1e1 meters)

- Maximum distance can be as small as 1 centimeter, at which point it would have minimal impact on the precision. There is a small performance cost to rebasing the origin more often.
- Rebased origin is computed from source transformation in full double precision for all Cesium actors, so there is *no* compounding error from repeated rebasing.

Appendix B: Precision in 3D Tiles / OWT WFF

- The geometry in a 3D tile define a *curved surface* on the actual WGS84 ellipsoid; *a tile is not a 2D plane*.



A single, low-detail tile showing curvature of the WGS84 ellipsoid

- A tile's center is defined in double-precision with a transformation matrix (64-bit floats) that transforms tile-local vertex positions to WGS84.
- Vertex positions are stored in single-precision 32-bit floating point, relative to a local origin defined by the transformation matrix. The local origin is usually at the center of the tile's axis-aligned bounding-box (AABB).
- The precision of positions depends on size of tile:

Tile radius	Worst case Vertex precision (approx.)
< 1 meter	1 micrometer (1e-6 meters)
< 10 meters	0.01 millimeter (1e-5 meters)
< 100 meters	0.1 millimeter (1e-4 meters)
< 1 kilometer	1 millimeter (1e-3 meters)
< 10 kilometers	1 centimeter (1e-2 meters)
< 100 kilometers	0.1 meter (1e-1 meters)
< 1,000 kilometers	1 meter (1e0 meters)
Entire Earth	10 meters (1e1 meters)

- Always do analysis / simulation with the most detailed (smallest) tiles. For example, analysis for a missile trajectory should use the most detailed tiles.
- High precision needs do *not* limit maximum size of dataset, because it can be broken into tiles of arbitrarily small radius.
- Cracks between adjacent tile edges are possible; guaranteed to be smaller (usually much smaller) than the vertex precision for tiles of that size.
- Above is worst-case precision. Precision is better on average and better near the center of the tile. Exact precision of any given position is only a function of the magnitude of that position relative to the tile's origin.