



Point Clouds with



3DTiles



June 27, 2017

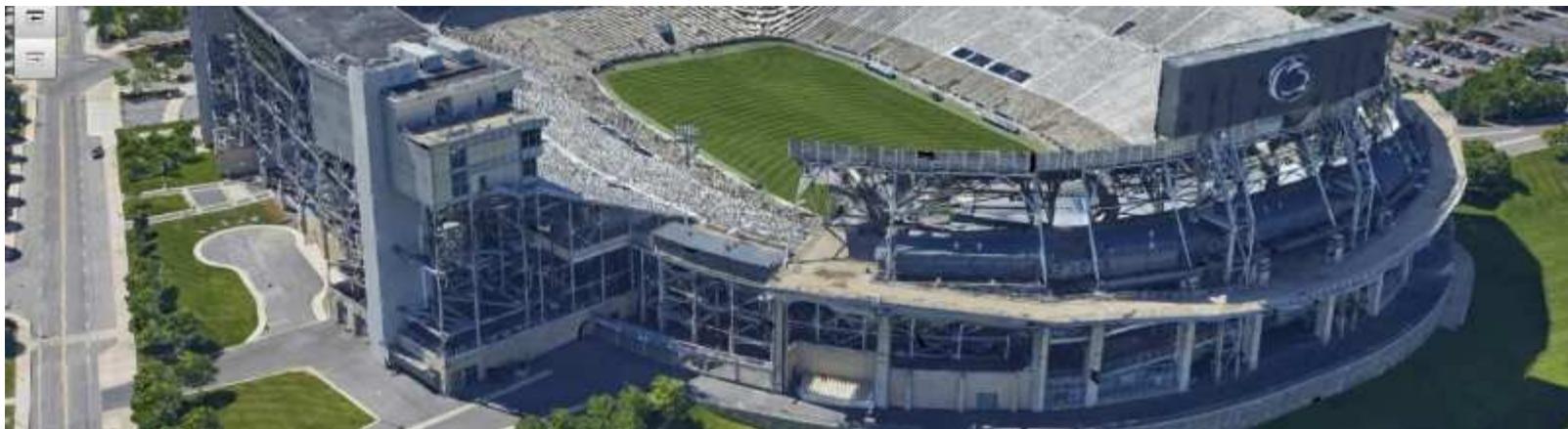
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Agenda



- Cesium
- 3D Tiles
- Point clouds: streaming visualization, fusion, styling, compressing



About Me



Started Cesium



Books on Virtual Globes, WebGL, OpenGL



Started 3D Tiles. Co-creator of glTF



Teach Computer Graphics



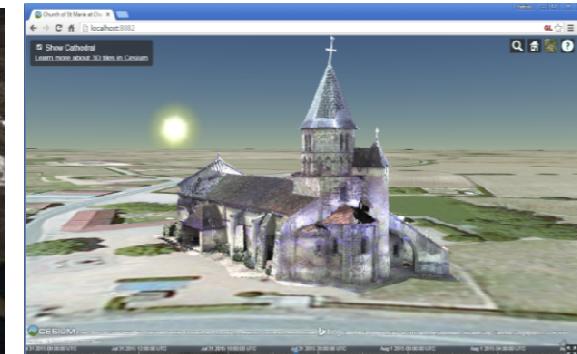
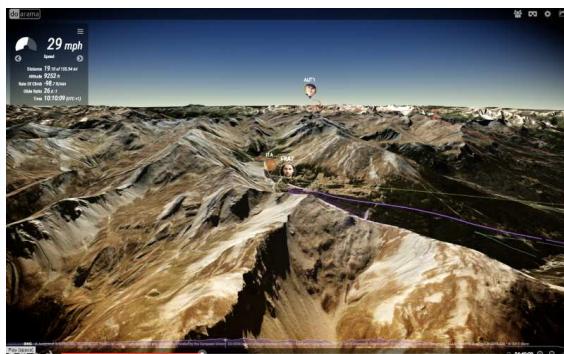
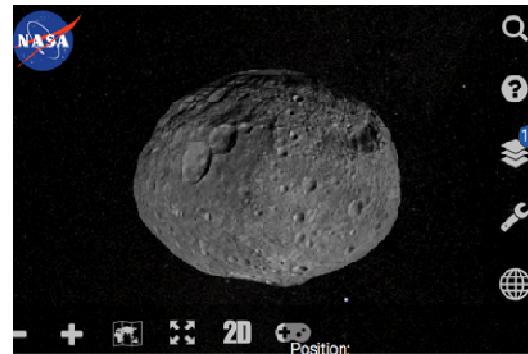
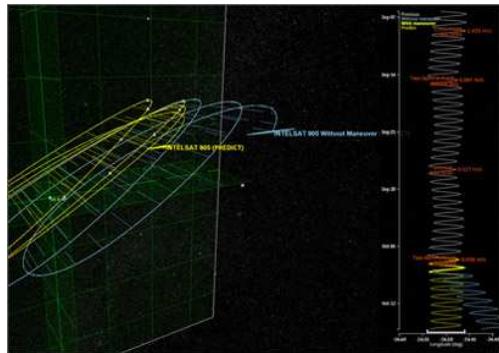
Open-Source, Geospatial, and Graphics Community Service



<http://www.seas.upenn.edu/~pcozzi/>

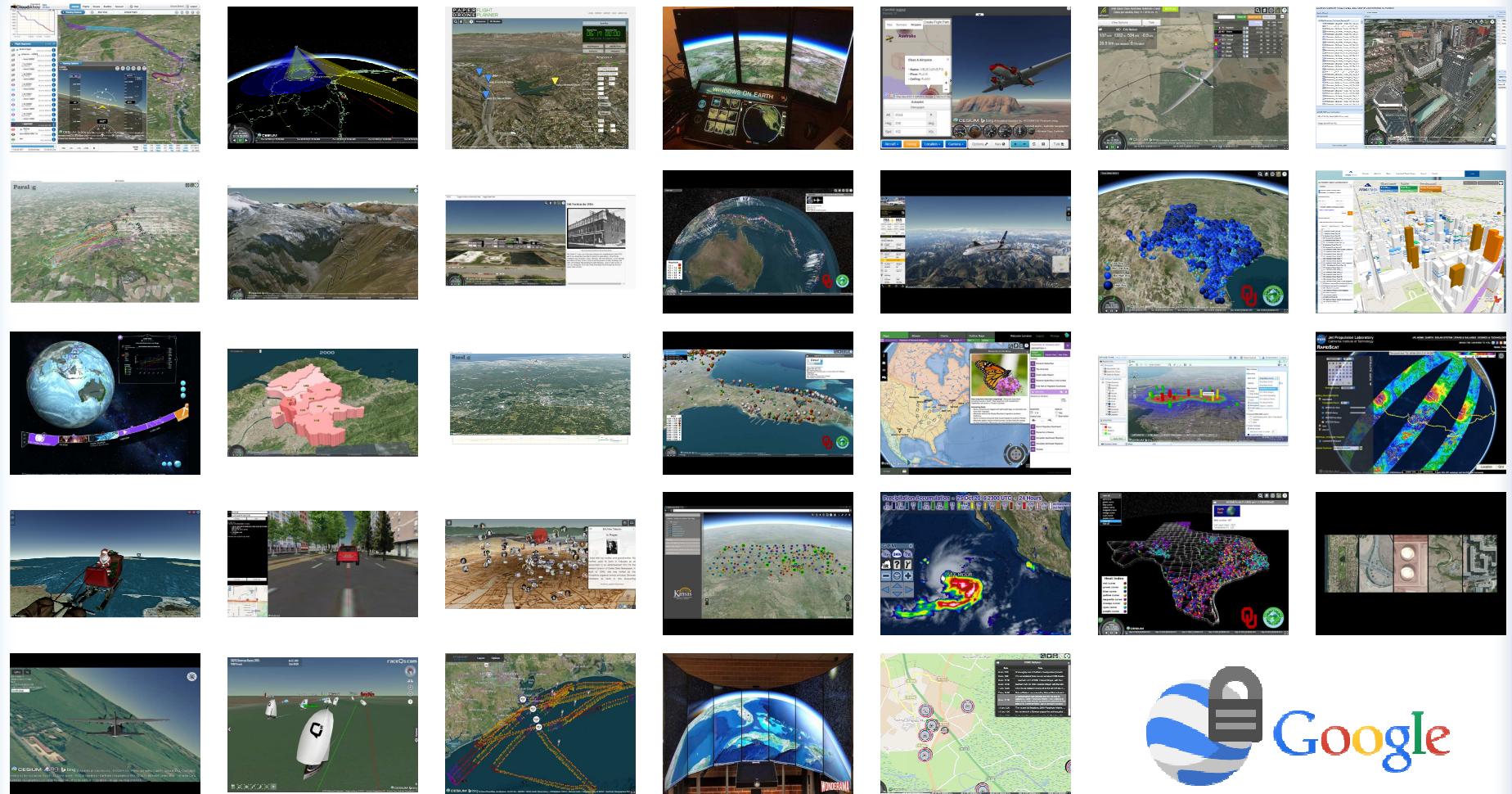


- Open-source JavaScript library for world-class 3D globes and maps
- Apache 2.0 license
- No plugins, cross platform, cross browser, cross device



<http://cesiumjs.org>

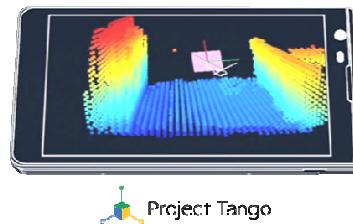
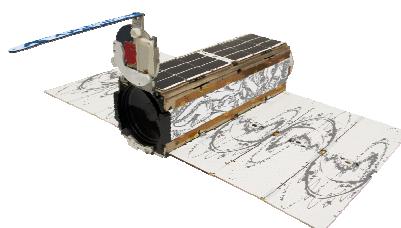
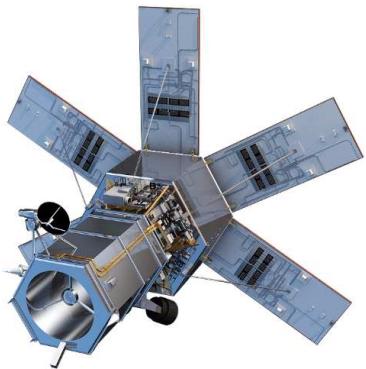
Google Earth to Cesium Showcases



<http://cesiumjs.org/for-google-earth-developers.html>



Explosive growth in 3D geospatial data!



Sensors everywhere!

cameras, LIDAR, RGBD, GPS, radar



CAD/BIM exteriors and interiors



Photogrammetry models



3D buildings



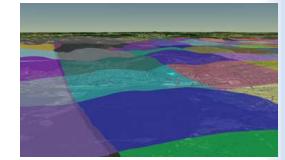
Terrain and imagery



Point clouds



Vector data



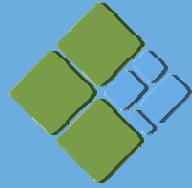
Massive heterogeneous
3D geospatial datasets



3D engines, e.g.,

Open specification for streaming massive
heterogeneous 3D geospatial datasets

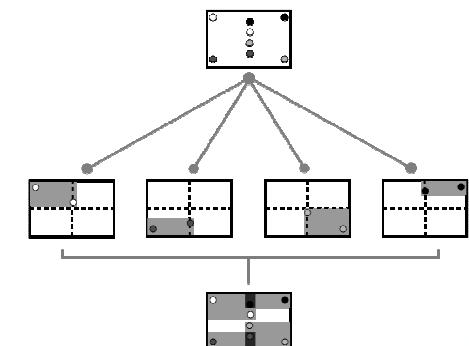
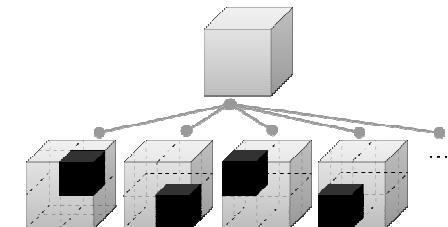
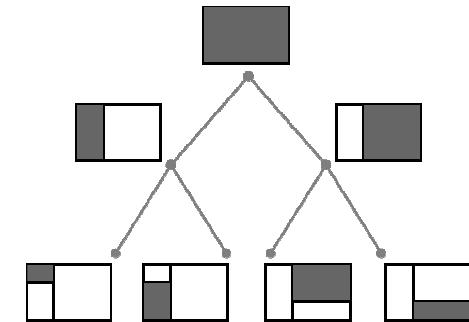
<https://github.com/AnalyticalGraphicsInc/3d-tiles>



3DTiles

CESIUM

- Spatial data structure supports **many tiling approaches**
 - Server/converter can decide what is optimal for a dataset
- **Heterogeneous** tile formats
- Client/runtime traverses **generic** spatial data structure





3D Tiles and OGC



3D Tiles is in the OGC Community Standard process

- Submission team from government, commercial, research, and academia
 - Analytical Graphics, Inc.
 - Bentley Systems, Inc.
 - Fraunhofer-Gesellschaft
 - Hochschule für Technik Stuttgart
 - US National Geospatial-Intelligence Agency (NGA)
 - virtualcitySYSTEMS GmbH



Hochschule
für Technik
Stuttgart

University of Applied Sciences

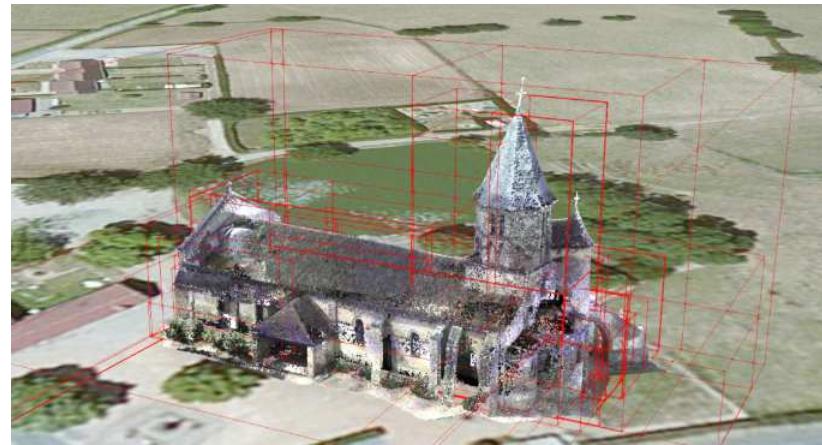


<http://cesiumjs.org/2016/09/06/3D-Tiles-and-the-OGC/>

Point Cloud Requirements



- Truly **3D**
- **Multiple LODs** in the same view
- **Non-uniform**
- **Add** to or **replace** child tiles
- **Data fusion** with terrain, imagery, buildings, etc.



3D Tiles Ecosystem



Exporters / Tilers



Bentley ContextCapture



Bentley MicroStation



VRICON



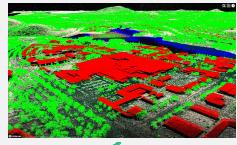
entwine



Westview3D



GAMESIM★



DATAiN



Virtual GIS



FME



Fraunhofer
IGD



LOPCS



@mattshax



Fraunhofer
IGD

cityzenith

Visualization engines



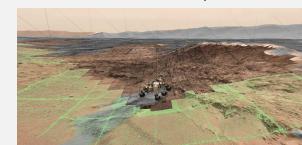
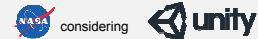
CESIUM®



OSG.JS



three.js prototype
SiteSee



Validator in-progress

Built on



KHRONOS
GROUP



Google

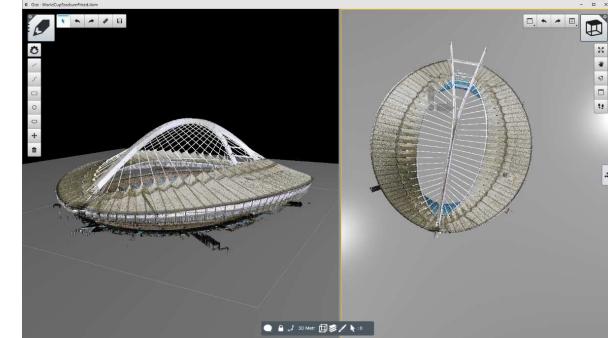


Microsoft



Oculus VR

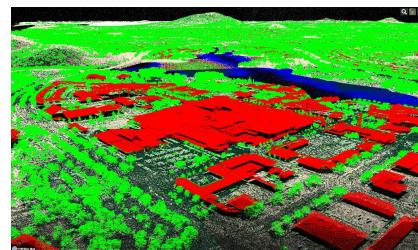
3D Tiles Point Cloud Ecosystem



Bentley MicroStation



Entwine



DATA
61



LOPoCS



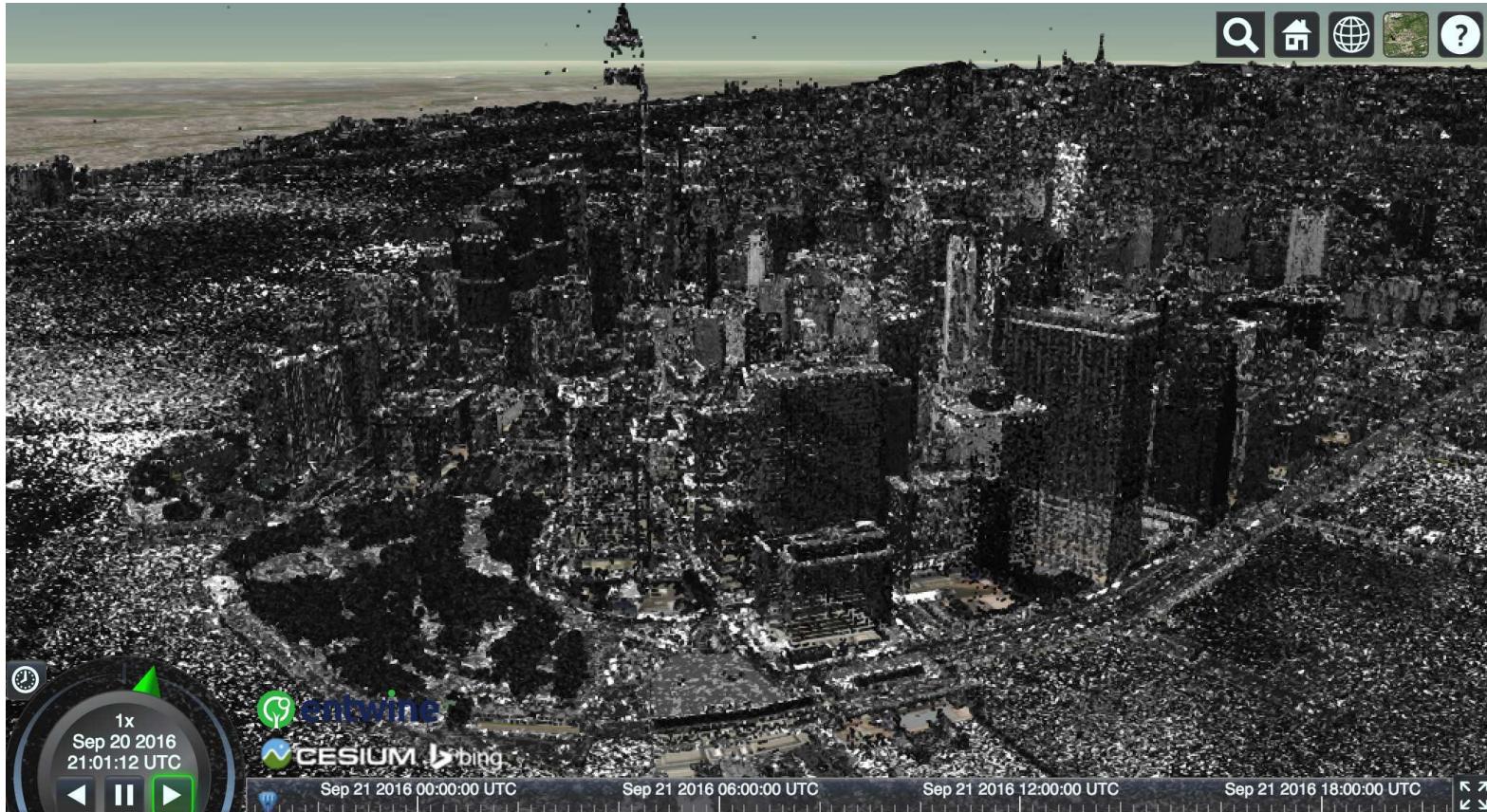
@mattshax

SAFE SOFTWARETM
FME

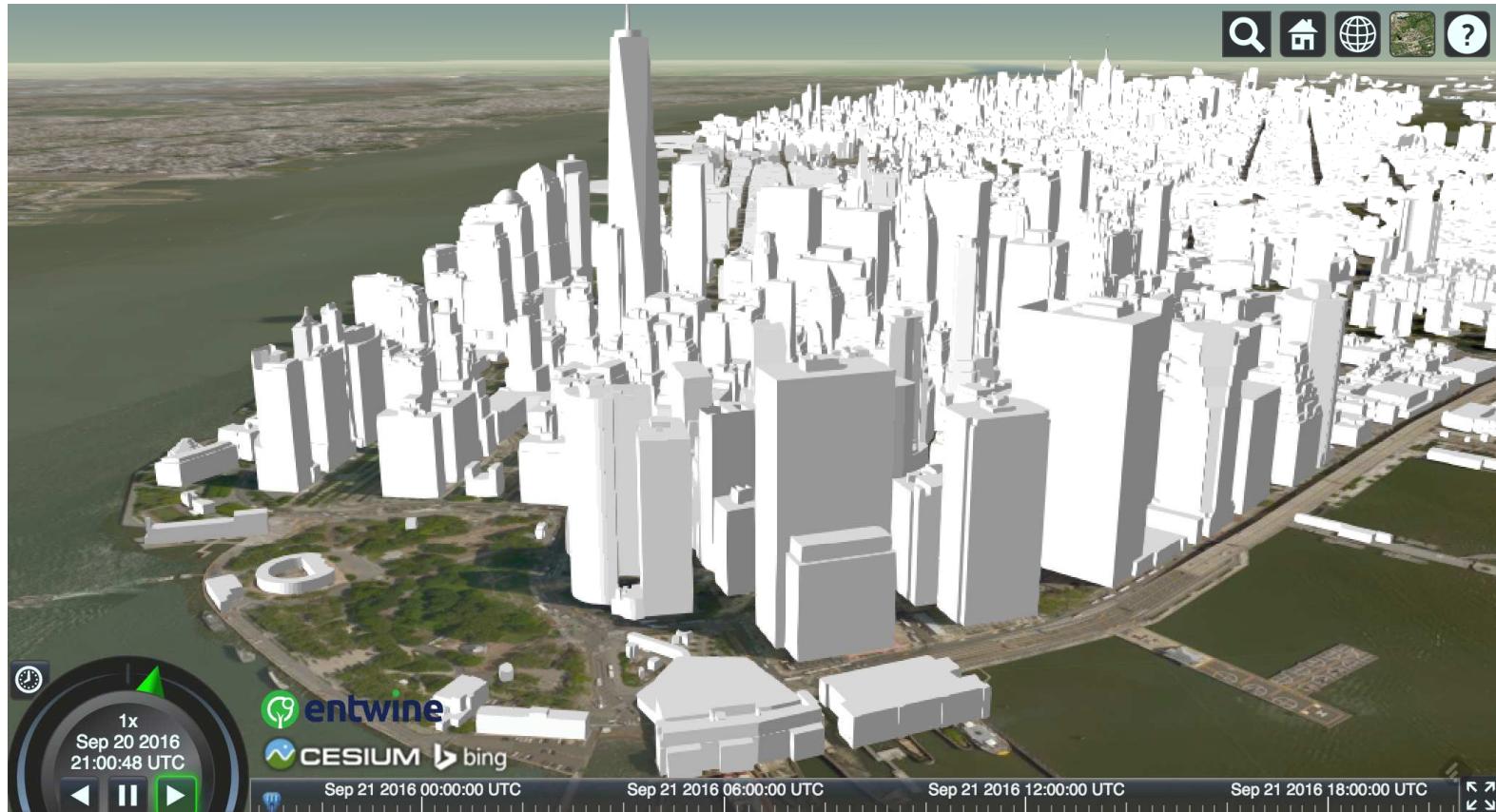
Data Fusion



Data Fusion



Data Fusion



Data Fusion



Data Fusion

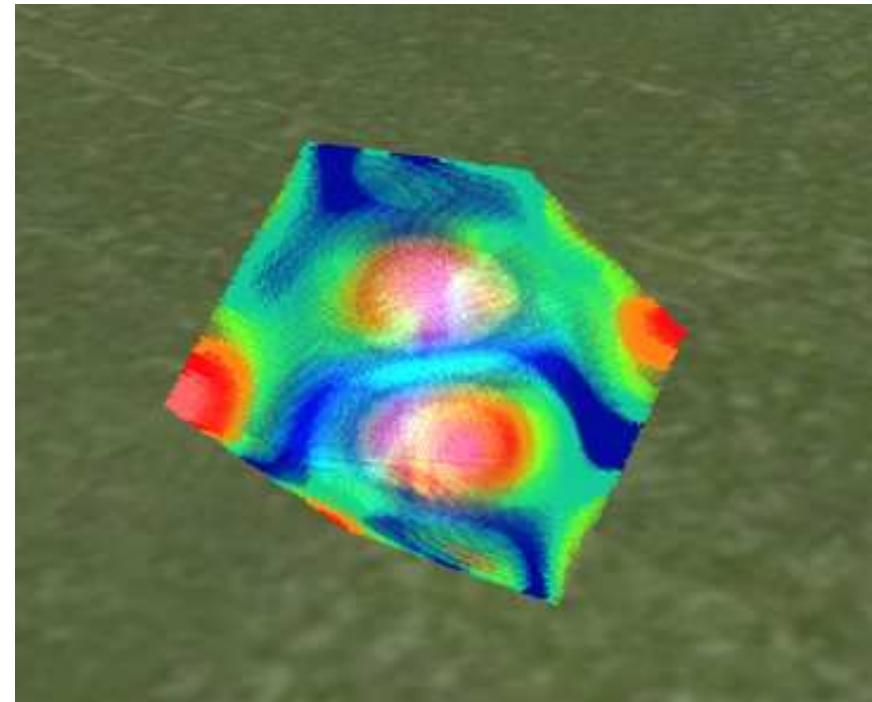


GPU-Accelerated Declarative Styling



- Use **per-point properties** in expressions to compute **color**, **transparency**, **transparency**, and **visibility**.
 - Evaluated in parallel per point on the GPU

```
{  
  "color" : {  
    "conditions" : [  
      ["${temperature} < 0.1", "color('#000099')"],  
      ["${temperature} < 0.2", "color('#00cc99', 1.0)"],  
      ["${temperature} < 0.3", "color('#66ff33', 0.5)"],  
      ["${temperature} < 0.4", "rgba(255, 255, 0, 0.1)"],  
      ["${temperature} < 0.5", "rgb(255, 128, 0)"],  
      ["${temperature} < 0.6", "color('red')"],  
      ["${temperature} < 0.7", "color('rgb(255, 102, 102)')"],  
      ["${temperature} < 0.8", "hsl(0.875, 1.0, 0.6)"],  
      ["${temperature} < 0.9", "hsla(0.83, 1.0, 0.5, 0.1)"],  
      ["true", "color('#FFFFFF', 1.0)"]  
    ]  
  }  
}
```



GPU-Friendly Compressed Tiles



- Optional **GPU-friendly compression**
 - **Quantized positions** – 16-bits per x, y, and z
 - **Oct-encoded normals** – 16-bit normals
 - **RGB565 colors** – 16-bit per color (point clouds)
- Benefits
 - No CPU decode cost
 - Stays compressed in GPU memory
 - Cheap or free decode in parallel on GPU

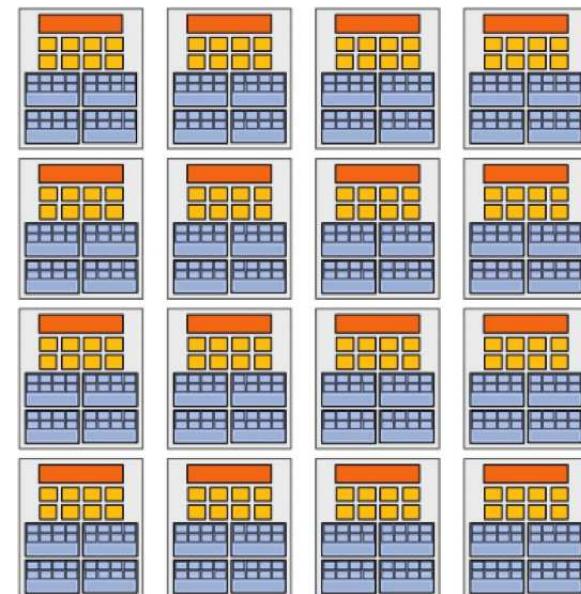


Image by Kayvon Fatahalian, CMU

Google Draco Compression



- Google adding point cloud (and mesh) compression extension to glTF, [#874](#)
 - Point cloud: 3.6x smaller than gzip
 - Mesh: 10-25x smaller than gzip
- Open-source encode/decode





cesiumjs.org

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Thanks for the 3D Tiles showcases! -





Bonus Slides

Refinement: replacement vs. additive



Replacement

$O(n \log n)$ tilesset

```
visit(tile)
{
    if (computeSSE(tile) <= pixel tolerance)
    {
        render(node);
    }
    else
    {
        foreach (child in tile.children)
            visit(child);
    }
}
```

Additive

$O(n)$ tilesset

```
visit(tile)
{
    render(tile);
    if (computeSSE(tile) > pixel tolerance)
    {
        foreach (child in tile.children)
            visit(child);
    }
}
```

