Browser based 3D Geovisualization

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Outline

- Session 1: Overview of browser based 3D visualization
  - 3D Graphics and Standards
  - Benefits of browser based 3D visualization
  - HTML5 and WebGL
- Session 2: Overview of browser based virtual globes for 3D Geo-visualization
  - WebGL Earth
  - OpenWebGlobe
  - Cesium
  - Overview of Cesium virtual globe
- Session 3: Hands-on with WebGL
- Session 4: Hands-on with Cesium

3D Graphics – A Primer

3D Coordinate Systems

- X-Axis
  - Horizontally left to right
- Y-Axis
  - Vertically top to bottom
- Z-Axis
  - Positive z coming out of the screen
  - Determines how far into or out of the screen an object can be drawn

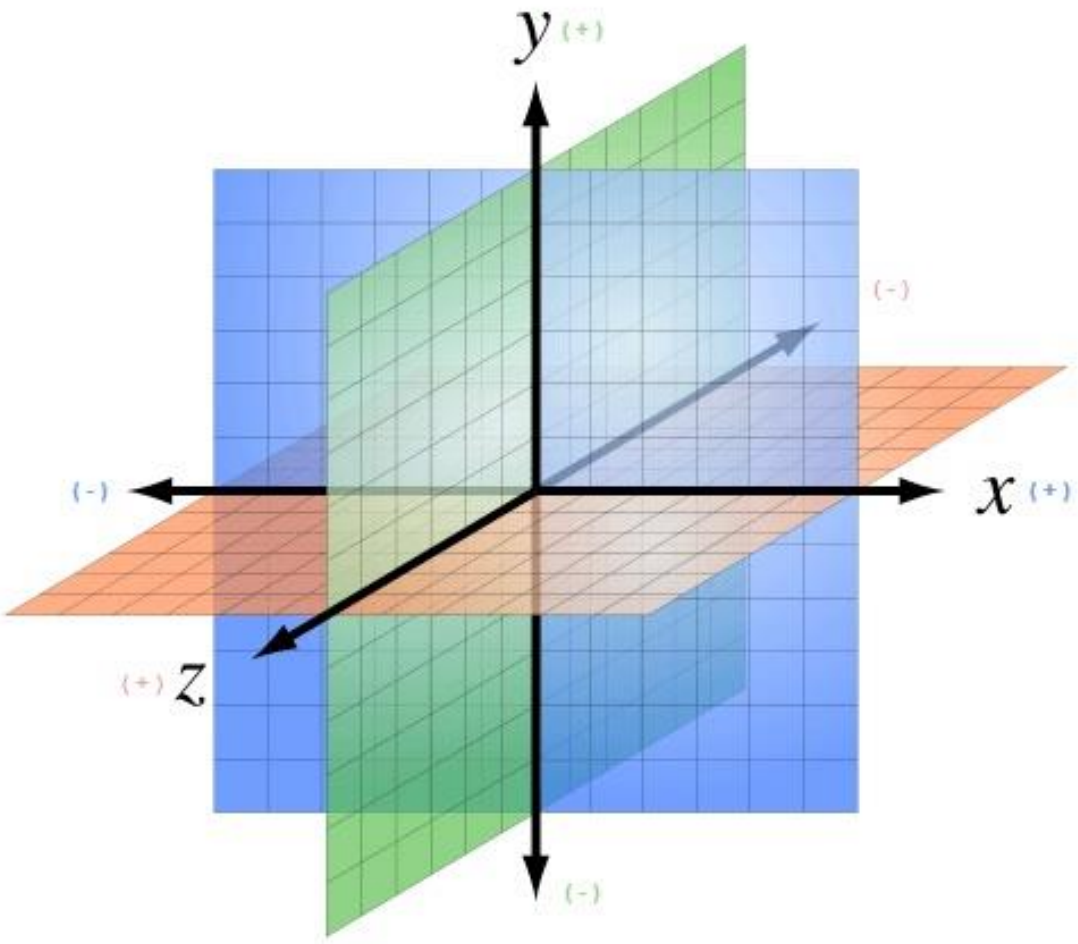


Image source: Parisi, Tony.,2012. *WebGL Up and Running*

Meshes, Polygons, and Vertices

- Mesh is an object composed of one or more polygonal shapes
- Constructed out of vertices (x,y,z triples) defining coordinate positions in 3D space
- Polygons used in meshes are usually triangles and quads
- 3D meshes are often referred to as models

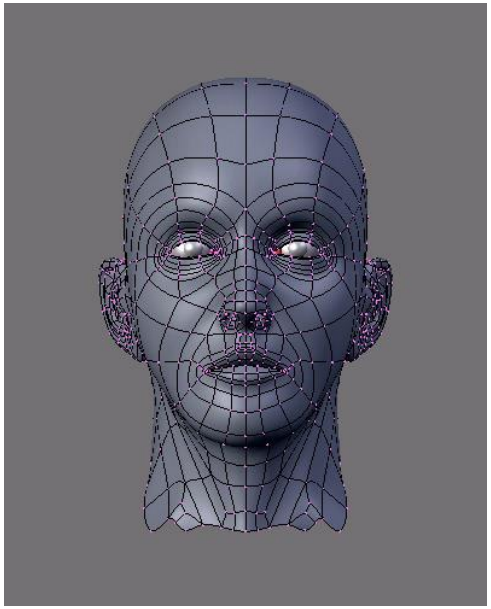


Image source: Parisi, Tony.,2012. *WebGL Up and Running*

Materials, Textures, and Lights

- Additional attributes of the surface of a mesh (beyond x, y, and z vertex positions)
  - Solid colour
  - Complex piece of information
    - E.g., how light reflects off the object or how shiny the object looks
  - Textures can define the literal surface look
    - E.g., image draped on the surface
  - Materials rely on the presence of one or more lights
    - Defines how a scene is illuminated

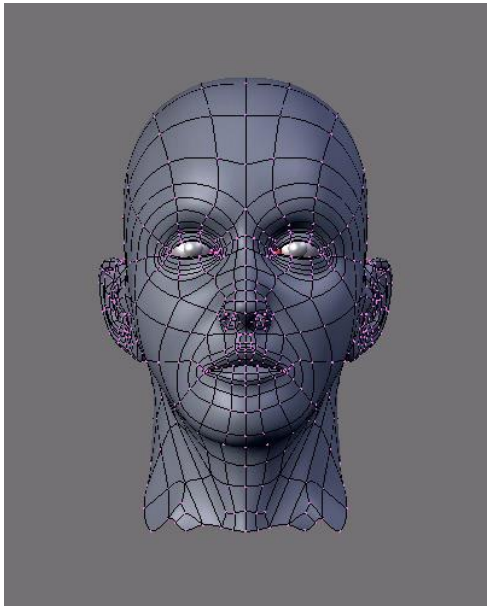


Image source: Parisi, Tony.,2012. *WebGL Up and Running*

Transforms and Matrices

- Transforms allow a rendered mesh to be scaled, rotated, and translated around
  - Without actually changing any value in its vertices
- A transform is represented by a matrix
  - A mathematical object containing an array of values used to compute the transformed position of vertices.

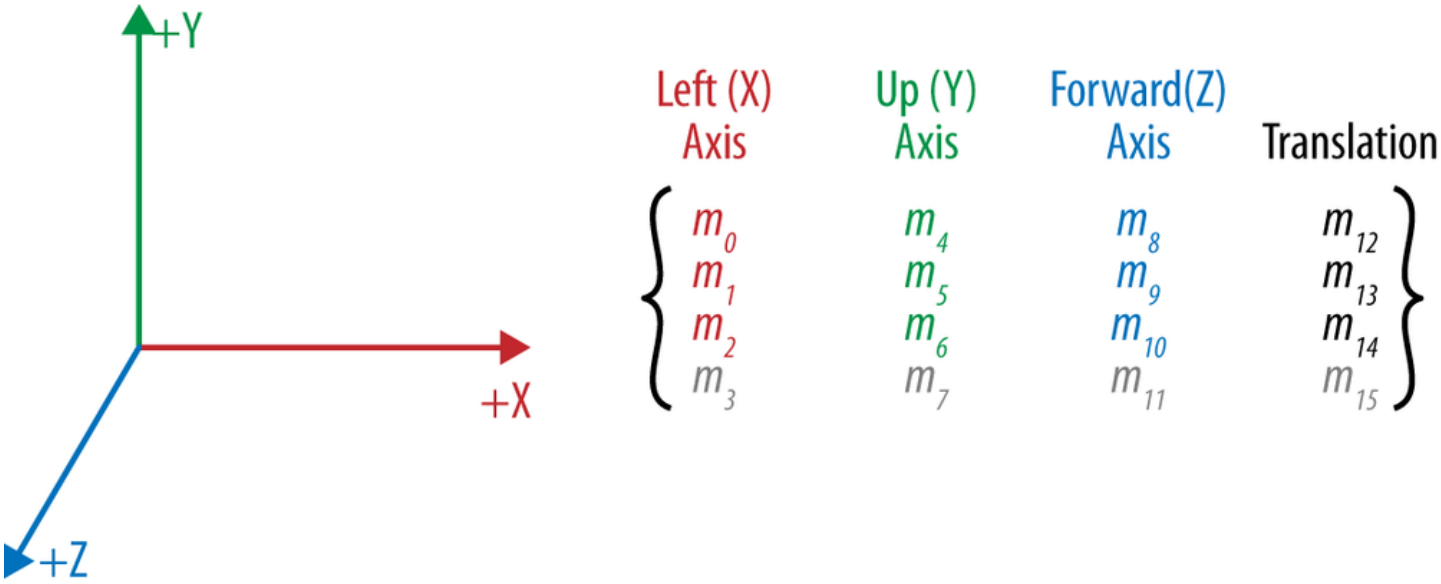


Image source: Parisi, Tony., 2014. *Programming 3D Applications with HTML5 and WebGL*

Cameras, Perspective, and Viewports

- Camera defines where (relative to the scene) the user is positioned and oriented
- Perspective is defined by real-world camera properties
  - such as the size of the field of view
- Viewport is defined by the window or canvas,
  - allows delivering the final rendered image of a 3D scene into a 2D viewport

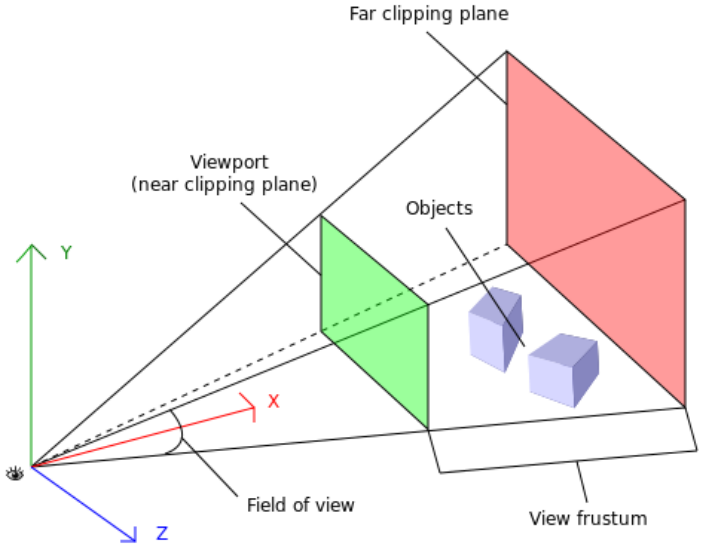


Image source: Parisi, Tony.,2012. *WebGL Up and Running*

Shaders

- Shaders allows rendering the final image for a mesh
  - Define how vertices, transforms, materials, lights, and the camera interact with one another to create the image
- A chunk of program code that implements algorithms to get the pixels for a mesh onto the screen
- Typically defined in a high-level C-like language and compiled into code usable by the GPU

Standards for 3D Graphics

COLLADA

- COLLAborative Design Activity
- XML-based schema
- Exchange format (.dae)
- Provides comprehensive encoding for
  - Geometry
  - Shaders and effects
  - Physics
  - Kinematics
  - Multiple representations of the same asset
- Supported by a wide variety of software products

More details: https://www.khronos.org/collada/

FBX and OBJ

- FBX
  - 3d asset exchange format
  - Provided by Autodesk
  - Supported by a few proprietary software products
  - Mostly useful in digital content creation applications

More details:
http://www.autodesk.com/products/fbx/overview

- OBJ
  - Geometry definition file format
  - Developed by Wavefront Technologies
  - Very simple data format for representing 3D geometry by
    - Position of each vertex
    - UV position of each texture coordinate vertex
    - Vertex normals
    - Faces with list of vertices
    - Texture vertices

More details: http://paulbourke.net/dataformats/obj/

glTF (intends to become „JPEG for 3D“)

- New format by Khronos Group
- Highly suitable for web applications
- Lightweight format
  - Mesh and animated data can be transmitted as binary
- Minimal client-side processing
  - Fast loading
- Run-time neutral
  - Can be implemented in all tools, apps and runtimes
- Supports materials, animations, skins, cameras and lights
- Flexible extension system
  - Additional features can be added

More details: https://github.com/KhronosGroup/glTF

Web standards for 3D (I)

- Virtual Reality Mark-up Language (VRML)
  - 3D on the web began with VRML, in 1995
  - Text file format for describing
    - 3D image sequences
    - User interactions (view, movement, rotation)
  - VRML viewing requires plug-in for web browsers

More details: https://www.w3.org/MarkUp/VRML/

- X3D
  - XML-based file format for representing 3D computer graphics
  - Successor to VRML
  - Supports shaders, geo-location, and many other features
  - Being used in domains such as medicine, CAD, GIS and others.
  - Like VRML, X3D requires plug-ins to be used on the browsers
  - X3DOM is an effort towards plug-in independent X3D support

More details: http://www.web3d.org/x3d/what-x3d

Web standards for 3D (II)

- Universal 3D (U3D)
  - Compressed file format for 3D graphics
  - Proposed by a consortium 3D Industry Forum in 2003
  - 3D objects can be inserted into PDF documents
  - Requires plug-ins for web browsers
- 3D Markup Language for Web (3DMLW)
  - XML-based file-format for creating 3D and 2D content on the Web
  - Requires plug-ins for web browsers
- Adobe Flash 3D
  - Support for 3D effects via the addition of new classes and methods
  - Requires proprietary Flash browser plug-in

Existing 3D standards (Summary)

- They are all interchange formats
  - Meant for exchanging data for further editing
  - Most of the formats are based on Scene Graph modeling paradigm
  - Can be loaded and rendered very efficiently by 3D viewers
- Models need a web-friendly runtime format
- Most solutions work only with certain browsers or with additional plug-ins
  - Plug-ins are inconvenient to install, troubleshoot and manage, and
  - Plug-ins may cause browser crashes and other problems
- Future browser generations do not support plug-ins anymore

Browser based 3D Visualization

Browser based 3D Visualization

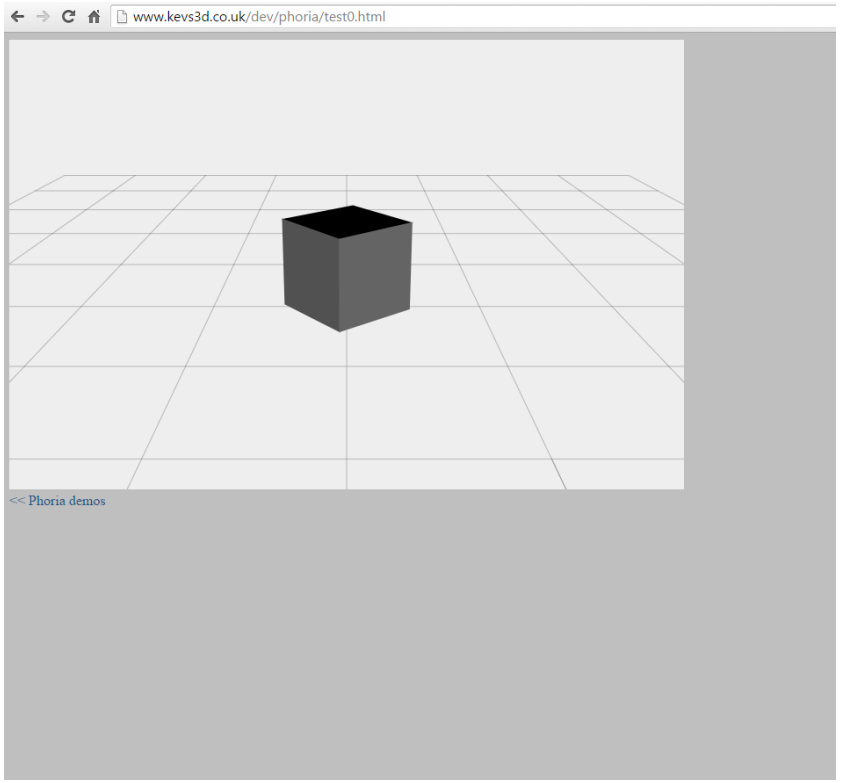
- 3D Visualization on the Web is challenging!
  - Large and complex data sets/volumes
  - Intricate textures and shapes
  - Requires high bandwidth and computing power
- 3D Visualization on the browsers is possible
  - Advancements in computer graphics
  - High computational capacities of devices
    - Faster CPUs, graphics processors, video cards, graphics accelerators
  - State-of-the-art web technologies
    - JavaScript, HTML5, WebGL
- Active research area
  - Numerous standards have been developed

HTML5

- HTML5
  - Mark-up language for structuring and presenting contents on the web
  - Open standard format
  - Provides common platform for web applications
- Introduced new elements
  - Audio/Video
  - **Canvas**
  - Scalable Vector Graphics (SVG)
  - Geo-location
  - Web Workers
  - Web Sockets
  - Many more..

HTML5 <canvas>

- Used to draw graphics, on the fly, via scripting
- The <canvas> element is only a container for graphics
  - The graphics are drawn by scripting
- Several methods for drawing
  - Path
  - Boxes
  - Circles
  - 3D Objects



More details: http://www.kevs3d.co.uk/dev/phoria/test0.html

WebGL

- WebGL: JavaScript implementation of OpenGL ES 2.0
  - Operating System independent
  - runs in all recent browsers (Chrome, Firefox, IE, Safari)
  - application can be located on a remote server
  - rendering is done within browser using local hardware
  - uses HTML5 canvas element
  - integrates with standard Web packages and apps
    - CSS
    - jQuery

HTML5 and WebGL

- HTML5 and WebGL have revolutionized the 3D web applications
- 3D capabilities can now be realized directly within the browsers
- Without any need for an additional plug-ins or extensions
- Hardware accelerated 3D functionality on the web
  - Utilizes hardware‘s graphics card memory
- Being used to solve complex problems
  - Medicine
  - CAD
  - Geospatial domain
    - Virtual Globes
  - Many more

Components of WebGL

- **HTML5 and CSS** for the user interface, including a <canvas> tag for the 3D scene
- **JavaScript** to process user events and communicate with servers if necessary
- **Shaders** running on the GPU to control rendering
  - Vertex shaders - handles the processing of individual vertices
  - Fragment shaders – handles the processing of fragments

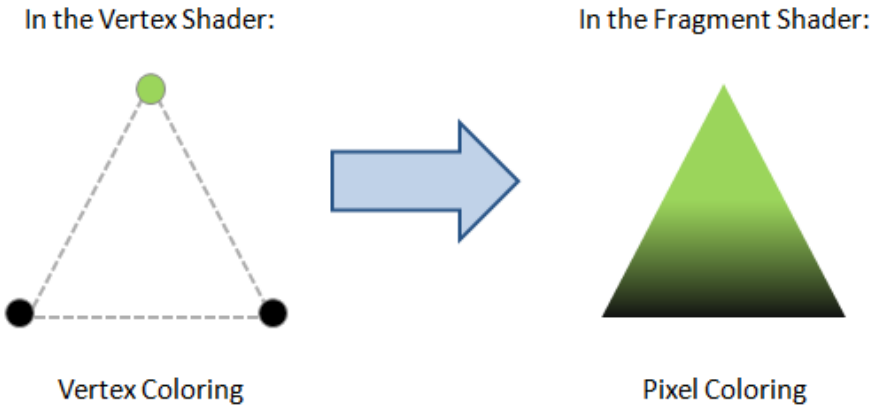


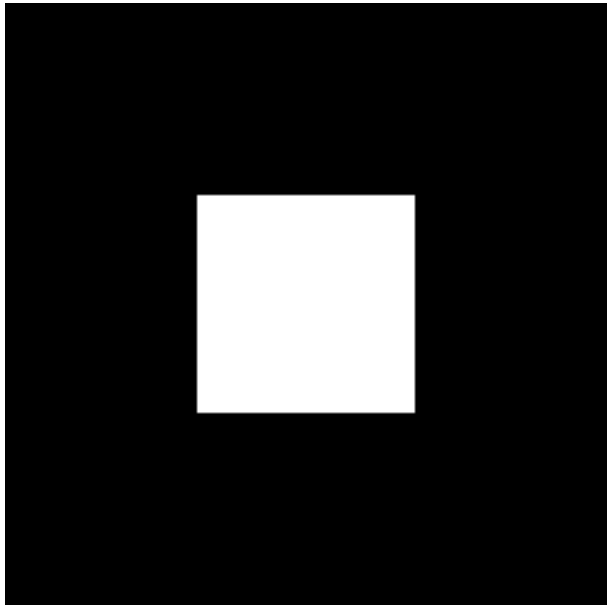
Image source: Cantor, Diego.,2012. *WebGL Beginner's Guide*

WebGL Programming in a nutshell

- All WebGL programs must do the following:
  1. Create a canvas element.
  2. Obtain a drawing context for the canvas.
  3. Initialize the viewport.
  4. Create one or more buffers containing the data to be rendered (typically vertices).
  5. Create one or more matrices to define the transformation from vertex buffers to screen space.
  6. Create one or more shaders to implement the drawing algorithm.
  7. Initialize the shaders with parameters.
  8. Draw.

Demonstration

- A simple WebGL example
- Generate one basic square
- Has all the elements of a more complex application
  - Vertex Shader
  - Fragment Shader
  - HTML Canvas



Source: Parisi, Tony.,2012. *WebGL Up and Running*

WebGL Code for a basic Square

```
function initWebGL(canvas) {
    var gl;
    try
    {
        gl = canvas.getContext("experimental-webgl");
    }
    catch (e)
    {
        var msg = "Error creating WebGL Context!: " + e.toString();
        alert(msg);
        throw Error(msg);
    }
    return gl;
}
function initViewport(gl, canvas)
{
    gl.viewport(0, 0, canvas.width, canvas.height);
}
var projectionMatrix, modelViewMatrix;
function initMatrices()
{
    // The transform matrix for the square - translate back in Z for the camera
    modelViewMatrix = new Float32Array(
                                [1, 0, 0, 0,
                                 0, 1, 0, 0,
                                 0, 0, 1, 0,
                                 0, 0, -3.333, 1]);

    // The projection matrix (for a 45 degree field of view)
    projectionMatrix = new Float32Array(
                                [2.41421, 0, 0, 0,
                                 0, 2.41421, 0, 0,
                                 0, 0, -1.002002, -1,
                                 0, 0, -0.2002002, 0]);

}
// Create the vertex data for a square to be drawn
function createSquare(gl) {
    var vertexBuffer;
                        vertexBuffer = gl.createBuffer();
    gl.bindBuffer(gl.ARRAY_BUFFER, vertexBuffer);
    var verts = [
         .5,  .5,  0.0,
        -.5,  .5,  0.0,
         .5, -.5,  0.0,
        -.5, -.5,  0.0
    ];
    gl.bufferData(gl.ARRAY_BUFFER, new Float32Array(verts), gl.STATIC_DRAW);
    var square = {buffer:vertexBuffer, vertSize:3, nVerts:4, primtype:gl.TRIANGLE_STRIP};
    return square;
}
```

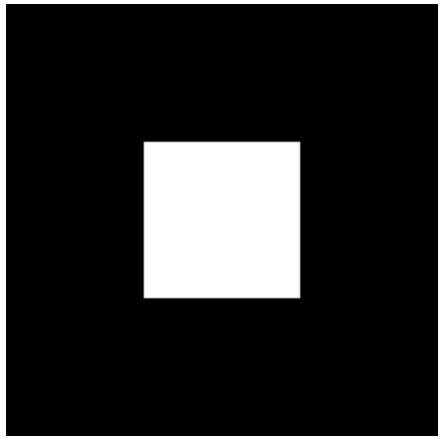
```
function createShader(gl, str, type) {
    var shader;
    if (type == "fragment") {
        shader = gl.createShader(gl.FRAGMENT_SHADER);
    } else if (type == "vertex") {
        shader = gl.createShader(gl.VERTEX_SHADER);
    } else {
        return null;
    }
    gl.shaderSource(shader, str);
    gl.compileShader(shader);
    if (!gl.getShaderParameter(shader, gl.COMPILE_STATUS)) {
        alert(gl.getShaderInfoLog(shader));
        return null;
    }
    return shader;
}
function initShader(gl) {
    var fragmentShader = createShader(gl, fragmentShaderSource, "fragment");
    var vertexShader = createShader(gl, vertexShaderSource, "vertex");
    // link them together into a new program
    . . . . . .
}
function draw(gl, obj) {
    // clear the background (with black)
    gl.clearColor(0.0, 0.0, 0.0, 1.0);
    gl.clear(gl.COLOR_BUFFER_BIT);
    // set the vertex buffer to be drawn
    gl.bindBuffer(gl.ARRAY_BUFFER, obj.buffer);
    // set the shader to use
    gl.useProgram(shaderProgram);

gl.vertexAttribPointer(shaderVertexPositionAttribute, obj.vertSize, gl.FLOAT, false, 0, 0);
    gl.uniformMatrix4fv(shaderProjectionMatrixUniform, false, projectionMatrix);
    gl.uniformMatrix4fv(shaderModelViewMatrixUniform, false, modelViewMatrix);
    // draw the object
    gl.drawArrays(obj.primtype, 0, obj.nVerts);
}

function onLoad() {
    var canvas = document.getElementById("webglcanvas");
    var gl = initWebGL(canvas);
    initViewport(gl, canvas);
    initMatrices();
    var square = createSquare(gl);
    initShader(gl);
    draw(gl, square);
}
```

Popular WebGL Frameworks

- WebGL is a low-level API and complex in nature
  - 150 lines of codes for just a basic square
- Frameworks are available to create WebGL contents quickly and easily
  - Avoids complex low-level programming
- Popular frameworks:
  - Three.js
    - Cross-browser JavaScript API
    - Create and display animated 3D graphics on browsers
    - Lightweight in nature
  - Scene.js
    - Open-source JavaScript API
    - Intended towards fast rendering of large numbers of individually picked objects

Three.js Code for a basic Square

```
<script src="../libs/Three.js"></script>
<script>
        function onLoad()
        {
                // Grab our container div
                var container = document.getElementById("container");

                // Create the Three.js renderer, add it to our div
                var renderer = new THREE.WebGLRenderer();
                renderer.setSize(container.offsetWidth, container.offsetHeight);
                container.appendChild( renderer.domElement );

                // Create a new Three.js scene
                var scene = new THREE.Scene();

                // Create a camera and add it to the scene
                var camera = new THREE.PerspectiveCamera( 45, container.offsetWidth / container.offsetHeight, 1, 4000 );
                camera.position.set( 0, 0, 3.3333 );
                scene.add( camera );

                // Now, create a rectangle and add it to the scene
                var geometry = new THREE.PlaneGeometry(1, 1);
                var mesh = new THREE.Mesh( geometry, new THREE.MeshBasicMaterial( ) );
                scene.add( mesh );

                // Render it
                renderer.render( scene, camera );
        }
</script>
```



Source: Parisi, Tony.,2012. *WebGL Up and Running*

X3DOM

- Open-source framework for integrating and manipulating X3D scenes as HTML5 DOM elements
- Rendered via
  - An X3D plug-in
  - Flash/Stage3D
  - **WebGL**

x3dom

- Declarative 3D scene description and run-time behaviour
  - Without any low-level JavaScript coding
- Library in a single JavaScript file (*x3dom.js*)
- When loaded, creates a new DOM object, *x3dom*
- When loaded, X3DOM automatically parses the HTML document for 3D models
  - Specifically, 3D-models specified inside <*x3d*> tag

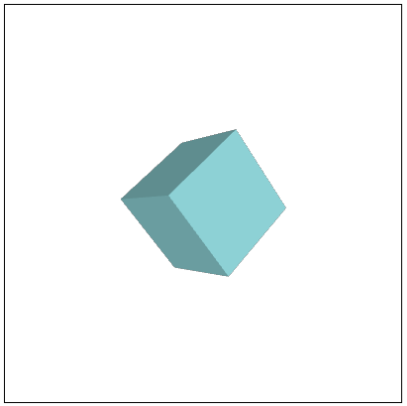
Demonstrations

- Hello World – demonstrates how a simple X3D scene can be displayed in browser

```
<!DOCTYPE html >
<html >
 <head>
   <link rel="stylesheet" type="text/css" href="x3dom.css" />
   <script type="text/javascript" src="x3dom.js"></script>
 </head>

 <body>
   <x3d xmlns="http://www.x3dom.org/x3dom" width="400px" height="400px" >
     <scene>
      <viewpoint position='0 0 10' ></viewpoint>
       <shape>
        <appearance>
          <material diffuseColor='0.603 0.894 0.909' ></material>
        </appearance>
        <box DEF='box' ></box>
       </shape>
     </scene>
   </x3d>
 </body>
</html>
```

Loads X3DOM library

Embedded X3D Content



Demo Link: http://examples.x3dom.org/example/x3dom_helloWorld.html

Session 2:
Virtual Globes

Concepts of Virtual Globes

- 3D-representation of the Earth
- Medium to visualize and interact with global geospatial data
  - Visualization of georeferenced data
- Provides sophisticated (and standardized) interaction and navigation capabilities
  - Freely move around in the virtual environment
  - Changing viewing angle and positions
- Multiple views on the surface of Earth
  - Geographical features (Terrains)
  - Man-made features (Roads or Buildings)
  - Demographic quantities (Population)

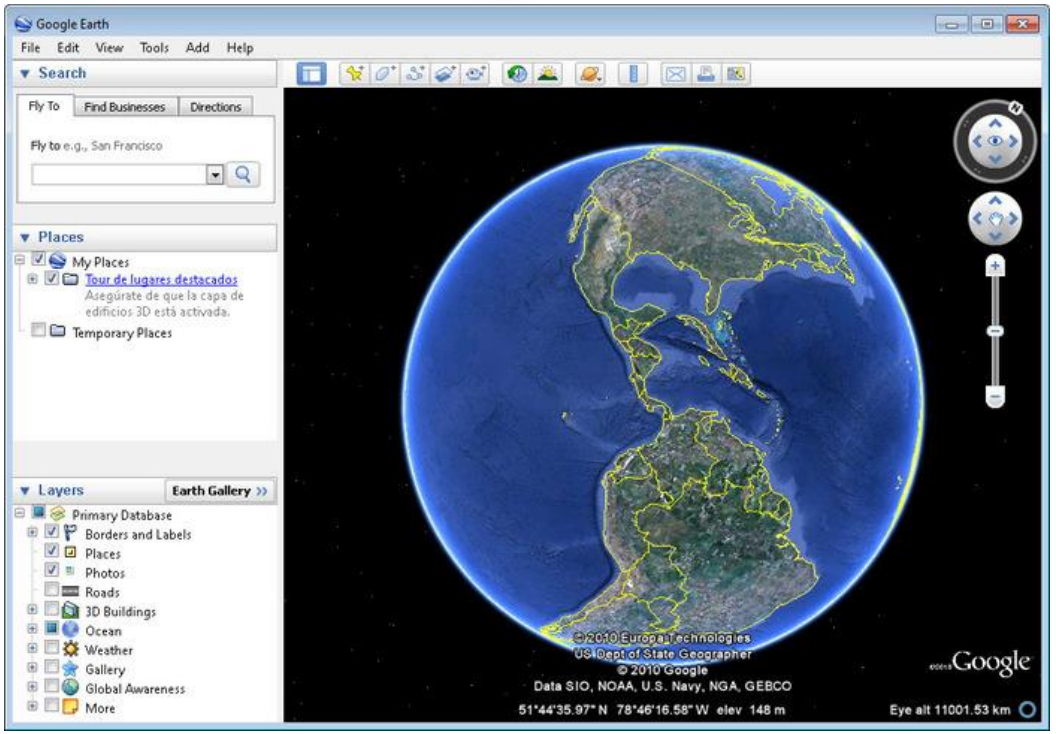
Popular Virtual Globes

- NASA World Wind
  - Open source virtual globe
  - Developed by NASA
  - Java based Software Development Kit
  - Supports
    - USGS satelite imageries,
    - aerial photography,
    - topographic maps,
    - KML and COLLADA files

More details: http://worldwind.arc.nasa.gov/java/

Popular Virtual Globes

- Google Earth
  - Free (not open source) virtual globe
  - Most popular till date
  - Supports
    - Satellite imageries,
    - aerial photography,
    - topographic maps,
    - KML and COLLADA files
  - Runs on most operating systems and devices (desktop, laptop, mobiles)
    - Google Earth plug-in for web browsers deprecated in December, 2015.



More details: https://www.google.com/earth/

How does WebGL benefit Virtual Globes?

- Development of web based virtual globes
  - Plug-in free
  - Cross-platform
  - Cross-browser
  - Cross-device
  - Free and open source
  - Seamless performance on browsers
- WebGL based virtual globes
  - WebGL Earth
  - OpenLayers 3
  - OpenWebGlobe
  - Cesium

  And many more..

WebGL Earth

- Open source JavaScript API
- Visualization of
  - maps,
  - satellite imagery and
  - aerial photography
- Features
  - Supports camera-dependent functionalities (rotation, zoom, tilt)
  - Supports existing maps from multiple sources (OSM, Bing)
  - Supports custom map tiles

More details: https://www.webglearth.com

OpenWebGlobe

- Open source SDK to develop web based applications
- Processes and interactively visualizes vast volumes of geospatial data
- Supports
  - Image Data
  - Elevation Data
  - Points of interest
  - Vector data
  - 3D Objects
- Parallel and scalable computing environment
  - Processes very large amount of data, upto TB
- Data must be pre-processed

More details: http://www.openwebglobe.org/

Cesium

- Open source JavaScript API
- Visualize high-resolution worldwide terrain
- Draw imagery layers using WMS, TMS, OSM, Bing and ESRI standards
- Draw vector data from GeoJSON and TopoJSON
- Draw 3D models using COLLADA and glTF
- Create data-driven time-dynamic scenes with CZML

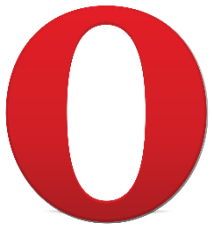
More details: https://cesiumjs.org/

Introduction to
Cesium WebGL Virtual Globe

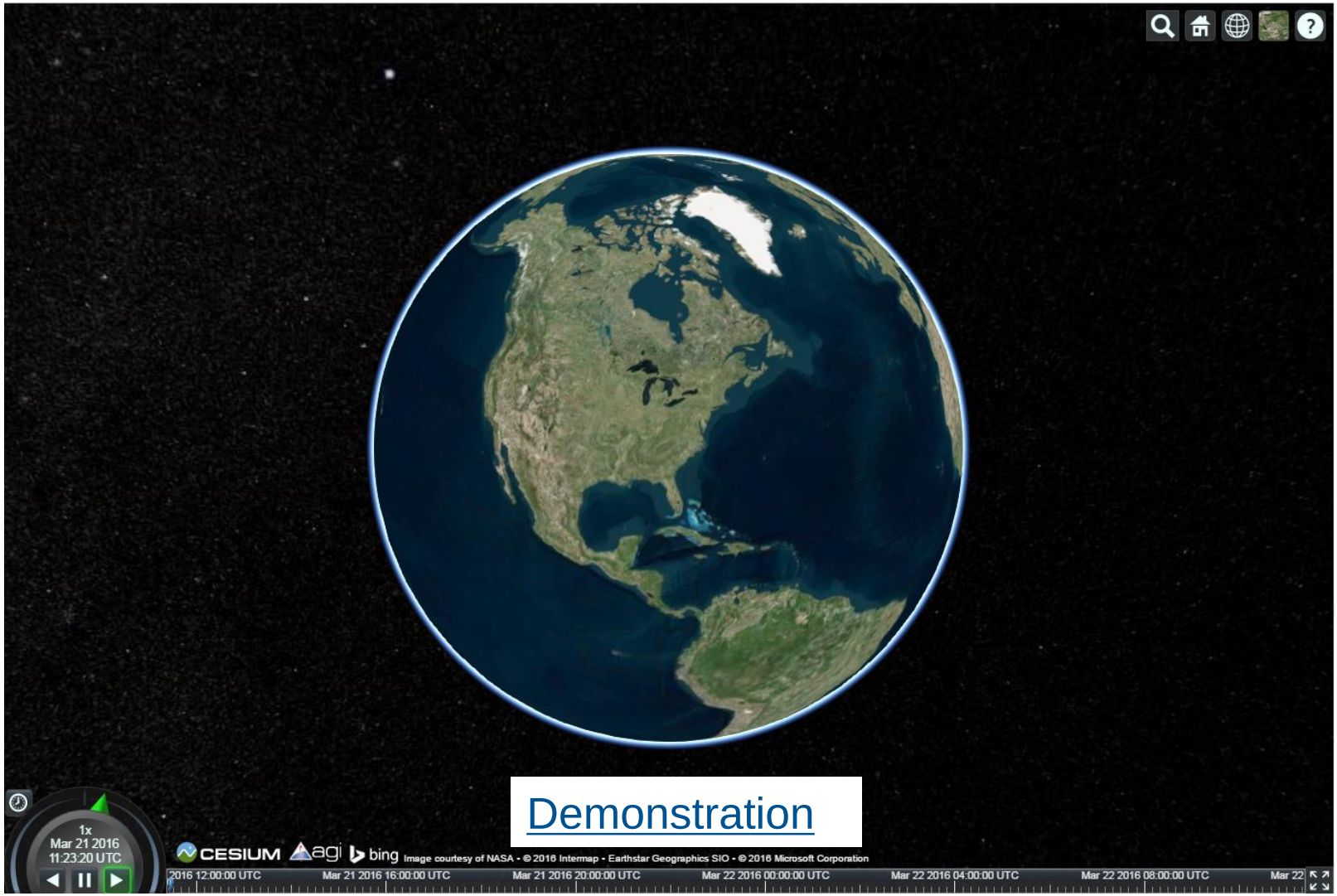
What is Cesium WebGL Virtual Globe?

- JavaScript library for 3D globes and 2D maps
- Built using WebGL and HTML5 standards
- Runs almost everywhere (including mobile devices)
- Apache 2.0 License
- Tuned for time-dynamic data
- Founded by US based company AGI, supported by a large community



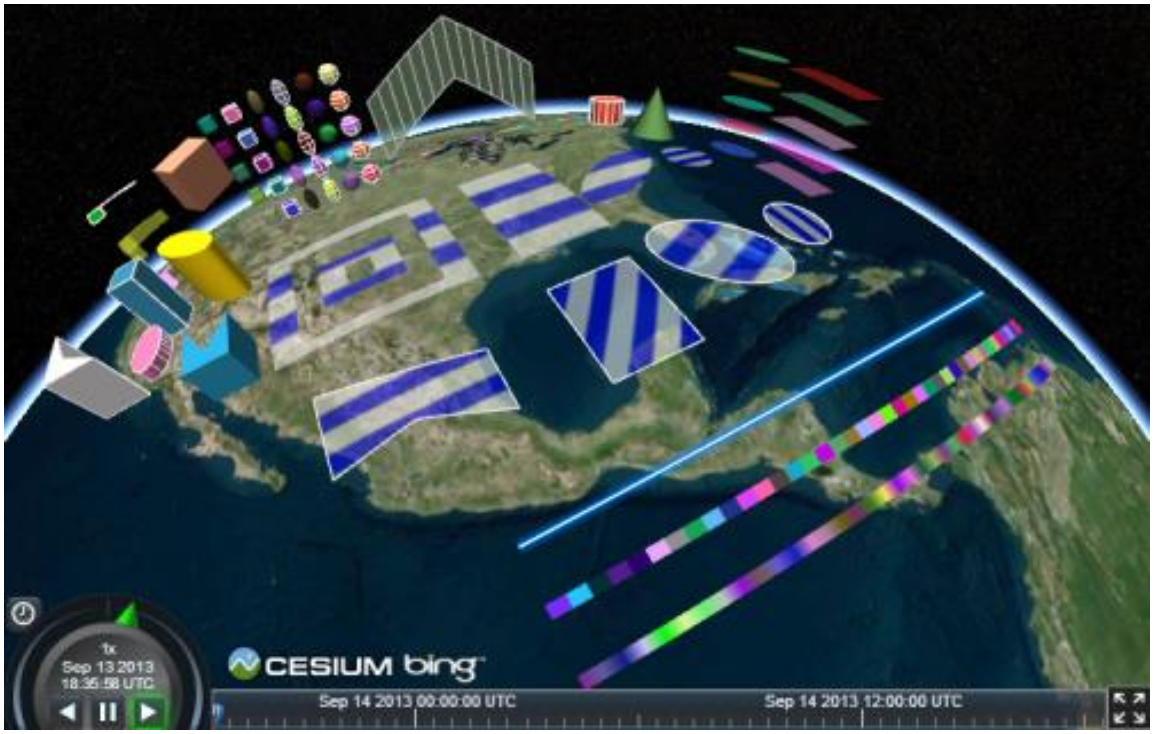

Cesium Viewer



Cesium Features

Vector Geometry

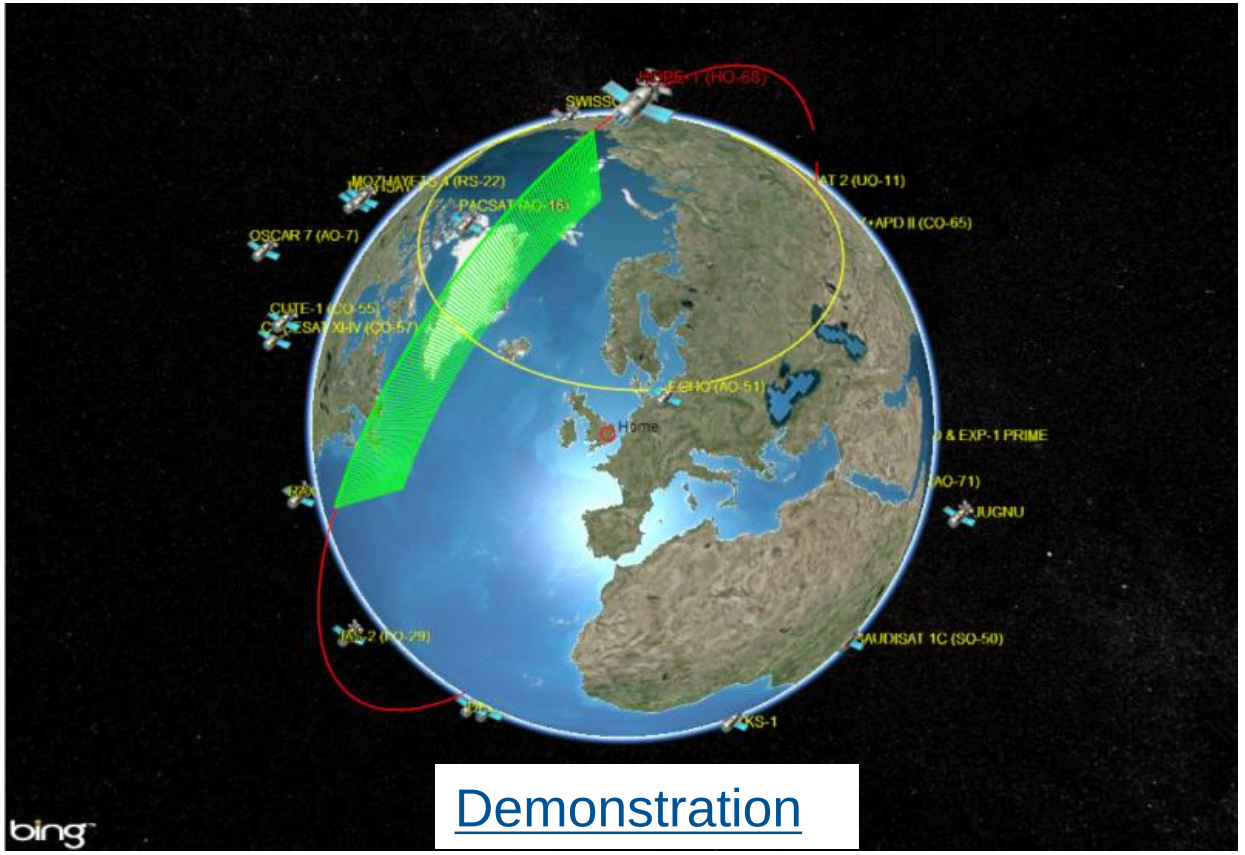
- Direct support for
  - KML
  - GeoJSON
  - TopoJSON
- Cesium API draws a wide variety of features and geometry



Demonstration

Time-Dynamic Visualization

- High-fidelity time-dynamic simulation
- Real-time telemetry streaming
- 4D visualization
- CZML



Demonstration

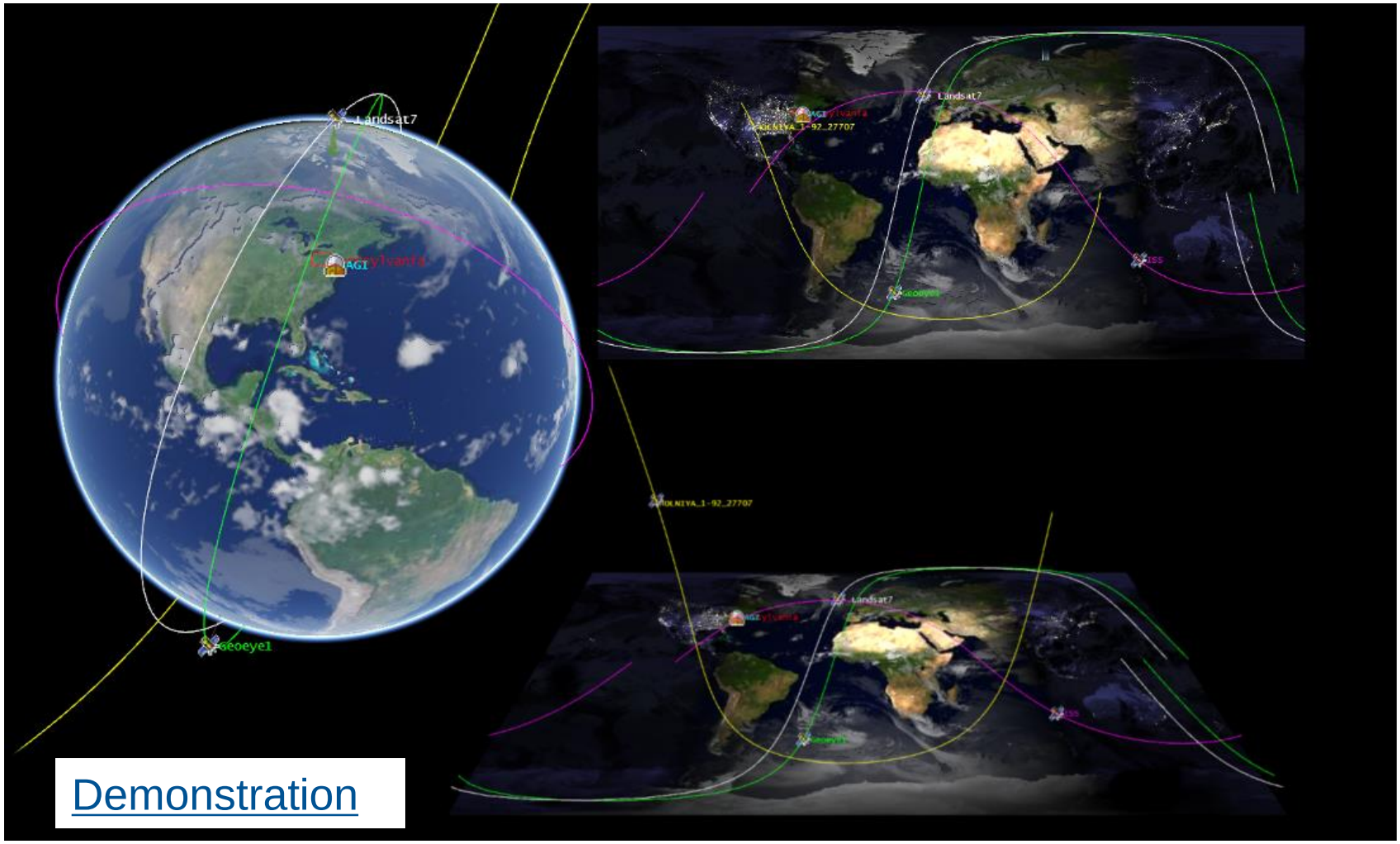
CZML

- Short for Cesium Modeling Language
- A streamable JSON scene description for data-driven visualization
- Describes properties that change over time
- Supports time-variation for
  - Lines
  - Points
  - Models
  - Graphical primitives

More details: https://github.com/AnalyticalGraphicsInc/cesium/wiki/CZML-Guide

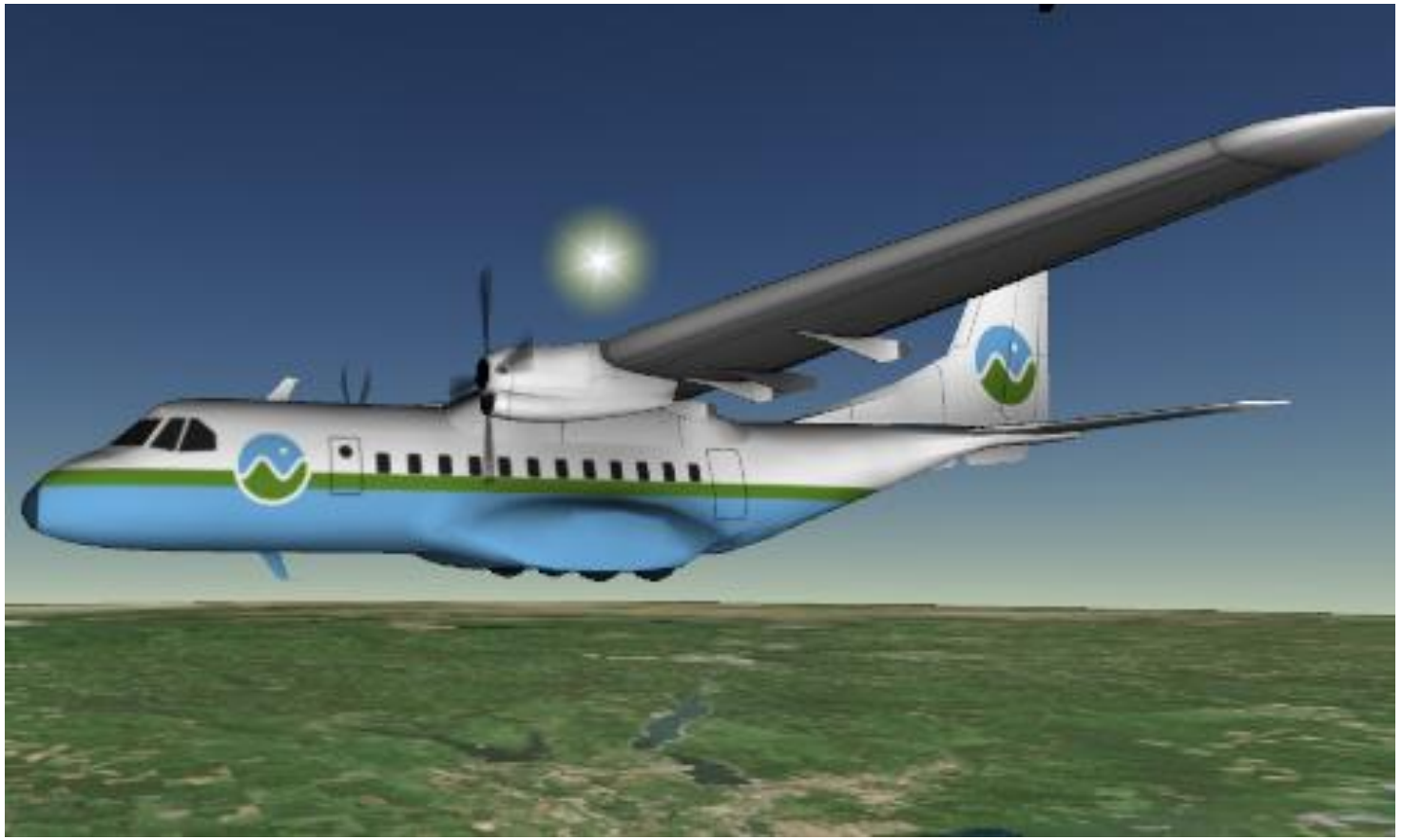
3D, 2D, and 2.5D Columbus View

- Use one API for three views



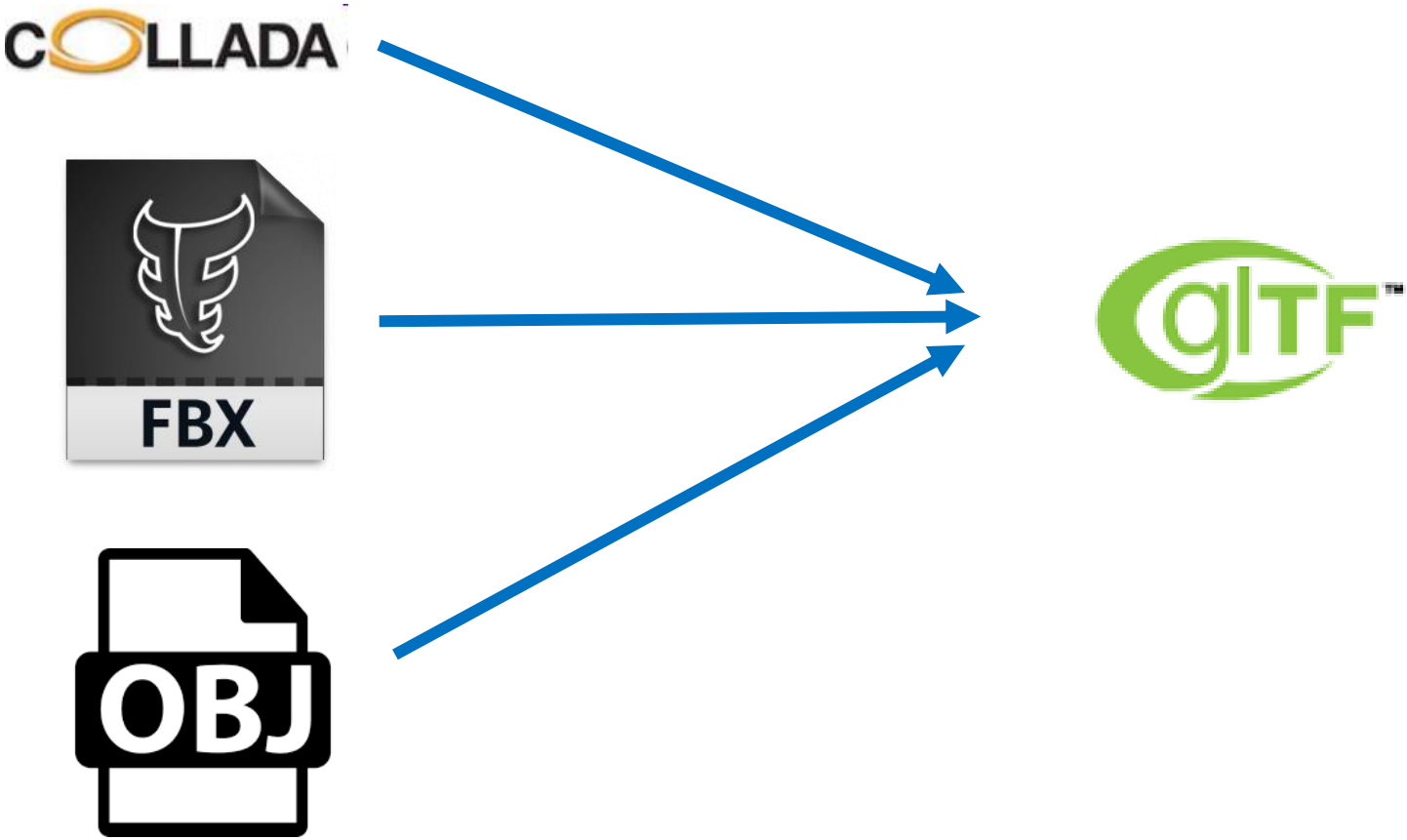
3D Models

- Visualize 3D models using glTF



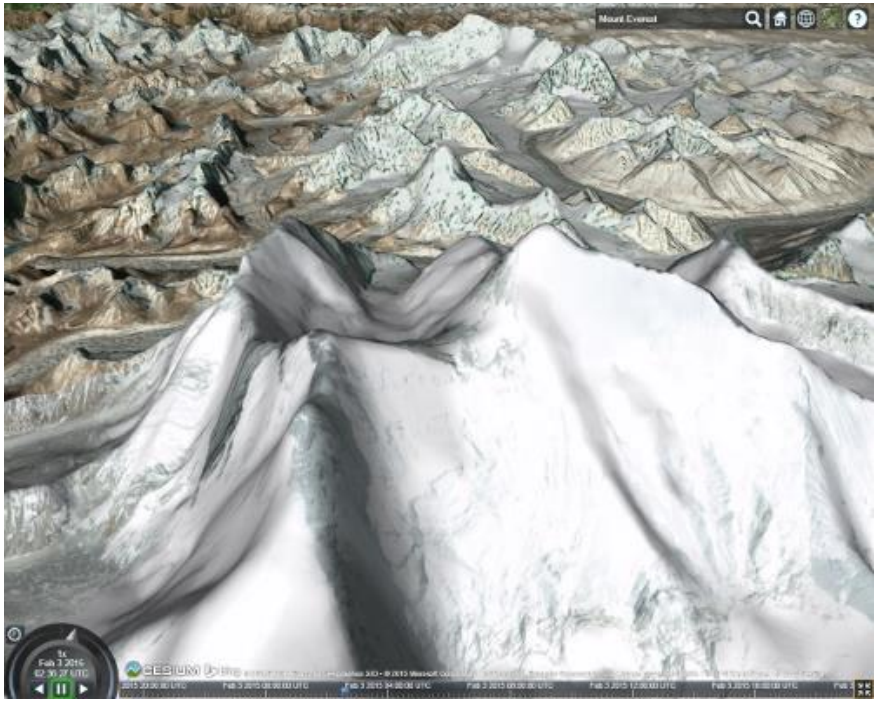
Demonstration

glTF Conversion



Global Terrain

- Stream high-resolution global terrain, using
  - Open-quantized mesh format
  - Traditional height maps
  - External terrains
- Cesium provides free access to 30 m resolution SRTM DEM
- User specified DEMs and DSMs are possible



Demonstration

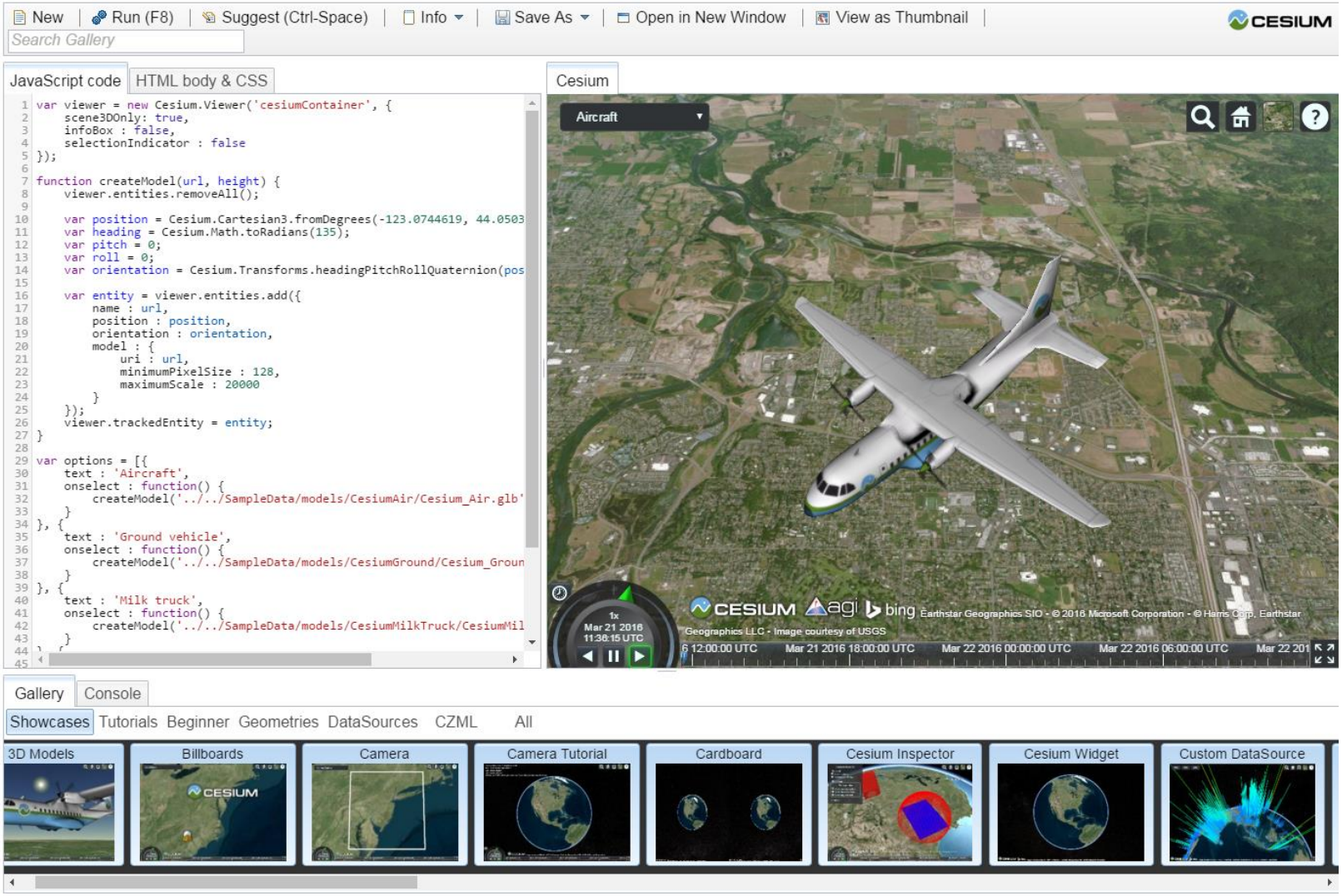
Imagery Layer

- Stream imagery
  - Supports a wide array of open standards
  - Custom tiling schemes

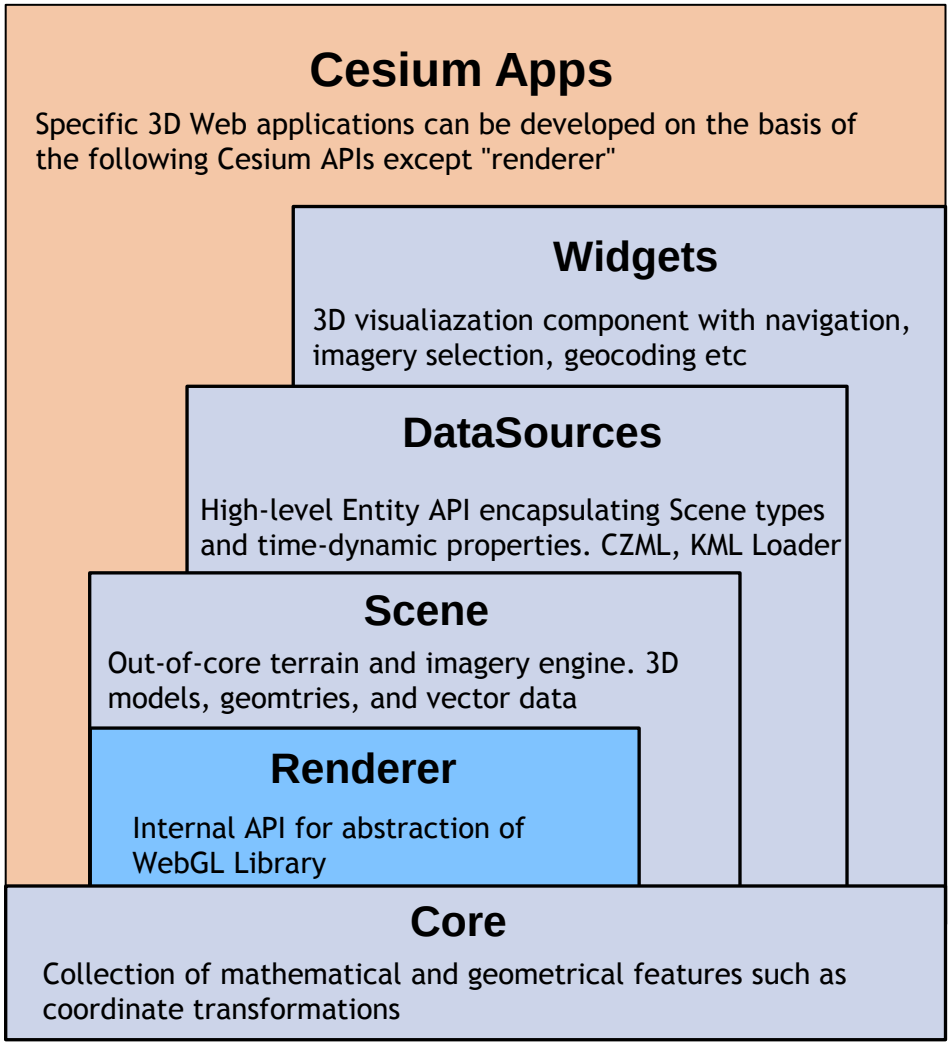
Demonstration

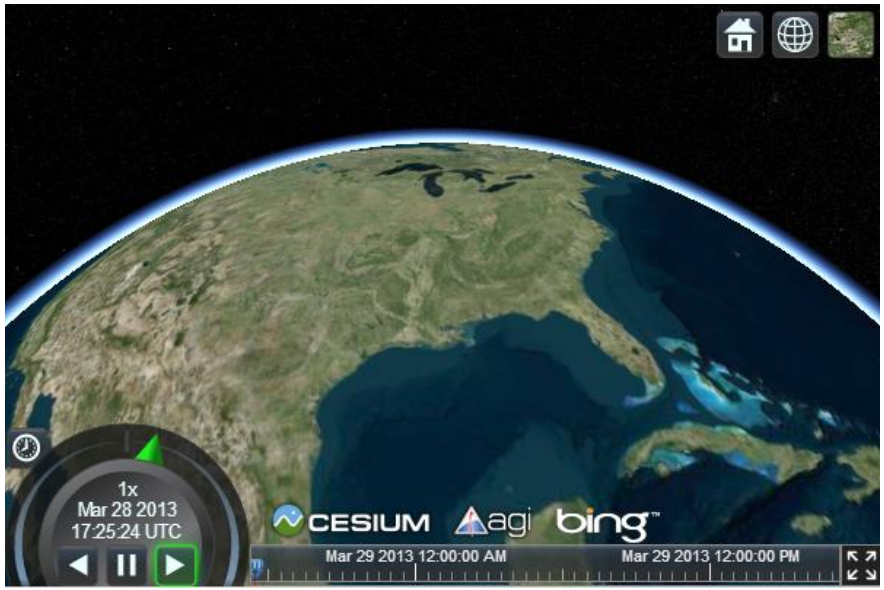
Cesium Sandcastle

Demonstration



Cesium Architecture

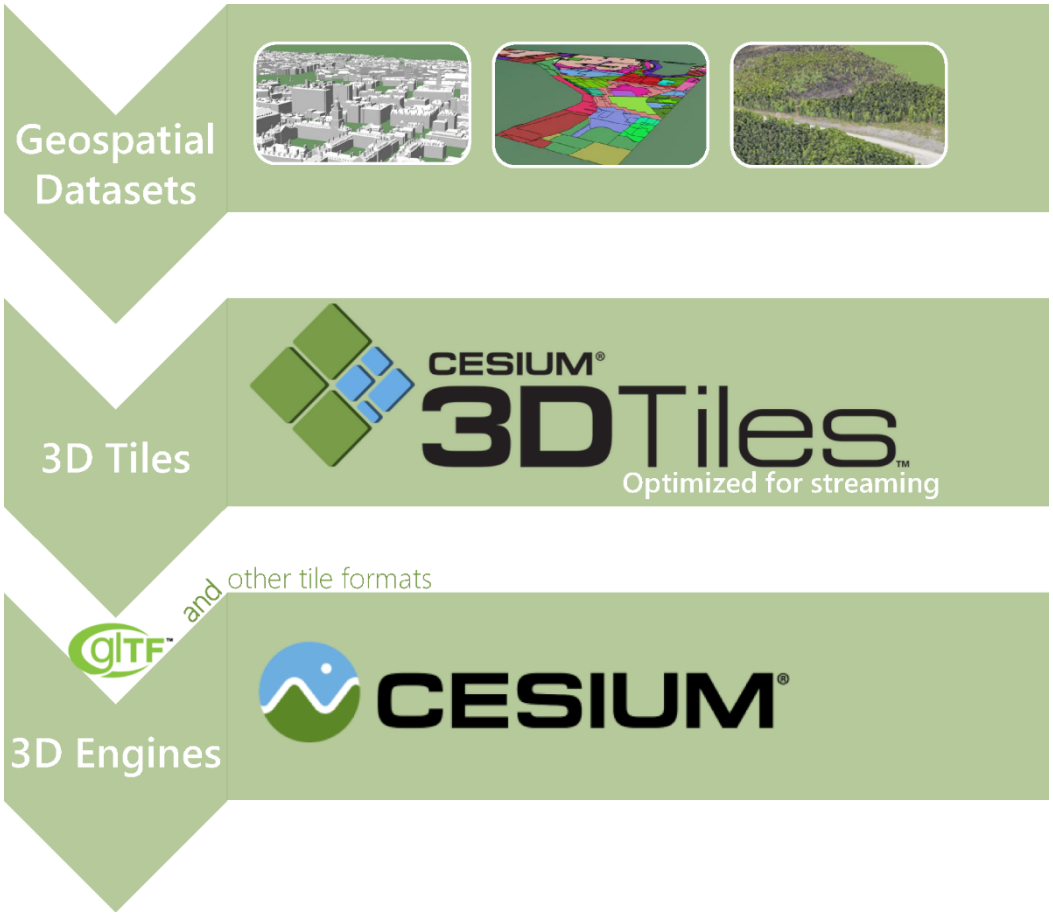




Source: https://cesiumjs.org/2015/05/15/Graphics-Tech-in-Cesium-Architecture/

3D Tiles by Cesium

- An open specification for streaming massive 3D geospatial datasets
  - Buildings
  - Trees
  - Point clouds
  - Temporal data
- Leverages glTF for models
- In-progress Work



Source: http://cesiumjs.org/2015/08/10/introducing-3d-tiles/

Session 3:
Hands-on with WebGL

Sample Datasets

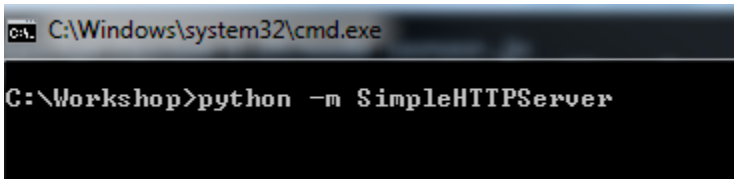
- Code examples from *WebGL Up and Running* by Tony Parisi

  https://github.com/tparisi/WebGLBook

- Download and extract the folder in C Drive
  - E.g. C:/Workshop

Setting up a local server

- Install Python
- Include C:/python27 in Windows Path
- Open Command Prompt
  - Navigate to C:/Workshop
  - Run python -m SimpleHTTPServer

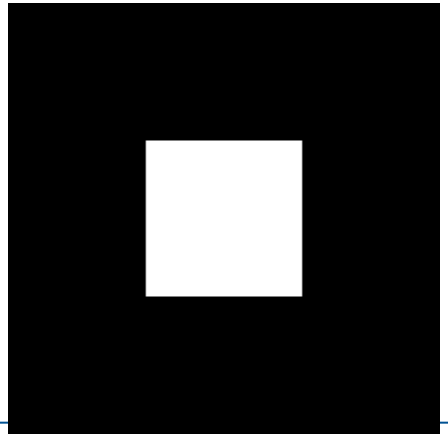


- Open a Web Browser
  - Go to http://localhost:8000/

Working with Three.js

- Chapter 2 -> example2-1.html

```
<script src="../libs/Three.js"></script>
<script>
        function onLoad()
        {
                // Grab our container div
                var container = document.getElementById("container");

                // Create the Three.js renderer, add it to our div
                var renderer = new THREE.WebGLRenderer();
                renderer.setSize(container.offsetWidth, container.offsetHeight);
                container.appendChild( renderer.domElement );

                // Create a new Three.js scene
                var scene = new THREE.Scene();

                // Create a camera and add it to the scene
                var camera = new THREE.PerspectiveCamera( 45, container.offsetWidth / container.offsetHeight, 1, 4000 );
                camera.position.set( 0, 0, 3.3333 );
                scene.add( camera );

                // Now, create a rectangle and add it to the scene
                var geometry = new THREE.PlaneGeometry(1, 1);
                var mesh = new THREE.Mesh( geometry, new THREE.MeshBasicMaterial( ) );
                scene.add( mesh );

                // Render it
                renderer.render( scene, camera );
        }
</script>
```

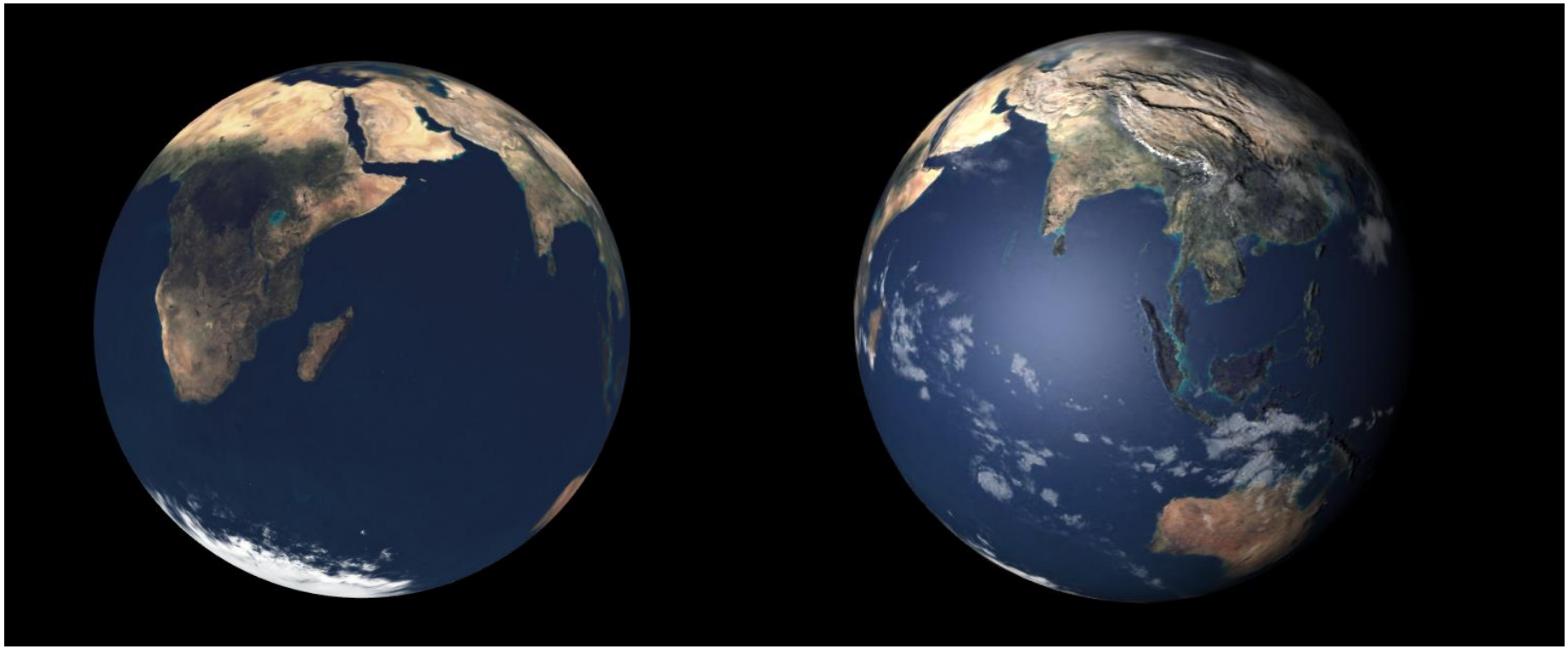


Working with Three.js

- Chapter 2 -> example2-2.html
  - Cube with an image wrapped onto its faces
  - Supports animation

Basic Earth Example

- Chapter 3
  - Creating realism with multiple textures



Live Coding with Three.js Library

- http://mrdoob.com/projects/htmleditor/

mrdoob.com/projects/htmleditor/

```
<!DOCTYPE html>
<html>
    <head>
        <meta charset="utf-8">
        <style>
            body {
                background-color: #ffffff;
                margin: 0;
                overflow: hidden;
            }
        </style>
    </head>
    <body>
        <script src="http://cdnjs.cloudflare.com/ajax/libs/three.js/r57/three.min.js"></script>
        <script>

            var camera, scene, renderer;
            var geometry, material, mesh;

            var init = function () {

                renderer = new THREE.CanvasRenderer();
                renderer.setSize( window.innerWidth, window.innerHeight );
                document.body.appendChild( renderer.domElement );

                camera = new THREE.PerspectiveCamera( 75, window.innerWidth / window.innerHeight, 1, 1000 );
                camera.position.z = 500;

                scene = new THREE.Scene();

                geometry = new THREE.CubeGeometry( 200, 200, 200 );
                material = new THREE.MeshBasicMaterial( { color: 0x0000ff, wireframe: true, wireframeLinewidth: 20 } );

                mesh = new THREE.Mesh( geometry, material );
                scene.add( mesh );

            }

            var animate = function () {

                requestAnimationFrame( animate );

                mesh.rotation.x = Date.now() * 0.0005;
                mesh.rotation.y = Date.now() * 0.001;

                renderer.render( scene, camera );

            }

            init();
            animate();

        </script>
    </body>
</html>
```

Exercise 1 – Working with Cube Geometry

```
<script>
      var camera, scene, renderer;
      var geometry, material, mesh;

      var init = function () {
            renderer = new THREE.CanvasRenderer();
            renderer.setSize( window.innerWidth, window.innerHeight );
            document.body.appendChild( renderer.domElement );

            camera = new THREE.PerspectiveCamera( 75, window.innerWidth / window.innerHeight, 1, 1000 );
            camera.position.z = 500;

            scene = new THREE.Scene();

            geometry = new THREE.CubeGeometry( 200, 200, 200 );
            material = new THREE.MeshBasicMaterial( { color: 0x000000} );

            mesh = new THREE.Mesh( geometry, material );
            scene.add( mesh );
       }
      var animate = function () {
      requestAnimationFrame( animate );
      mesh.rotation.x = Date.now() * 0.0005;
      mesh.rotation.y = Date.now() * 0.001;
      renderer.render( scene, camera );
      }

      init();
      animate();
    </script>
```

Try changing the dimensions of the cube

Try changing the colour of the cube

Try changing the rotation speed of the cube

Exercise 2 – Adding different geometries

Sphere Geometry

```
<script>
      var camera, scene, renderer;
      var geometry, material, mesh;

      var init = function () {
            renderer = new THREE.CanvasRenderer();
            renderer.setSize( window.innerWidth, window.innerHeight );
            document.body.appendChild( renderer.domElement );

            camera = new THREE.PerspectiveCamera( 75, window.innerWidth / window.innerHeight, 1, 1000 );
            camera.position.z = 500;

            scene = new THREE.Scene();

            geometry = new THREE.SphereGeometry( 100, 100, 100 );
            material = new THREE.MeshBasicMaterial( { color: 0x000000} );

            mesh = new THREE.Mesh( geometry, material );
            scene.add( mesh );
       }
      var animate = function () {
      requestAnimationFrame( animate );
      mesh.rotation.x = Date.now() * 0.0005;
      mesh.rotation.y = Date.now() * 0.001;
      renderer.render( scene, camera );
      }

      init();
      animate();
    </script>
```

Try changing the dimensions of the sphere

Try changing the colour of the sphere

Try changing the rotation speed of the sphere

Exercise 3 – Adding different geomtries

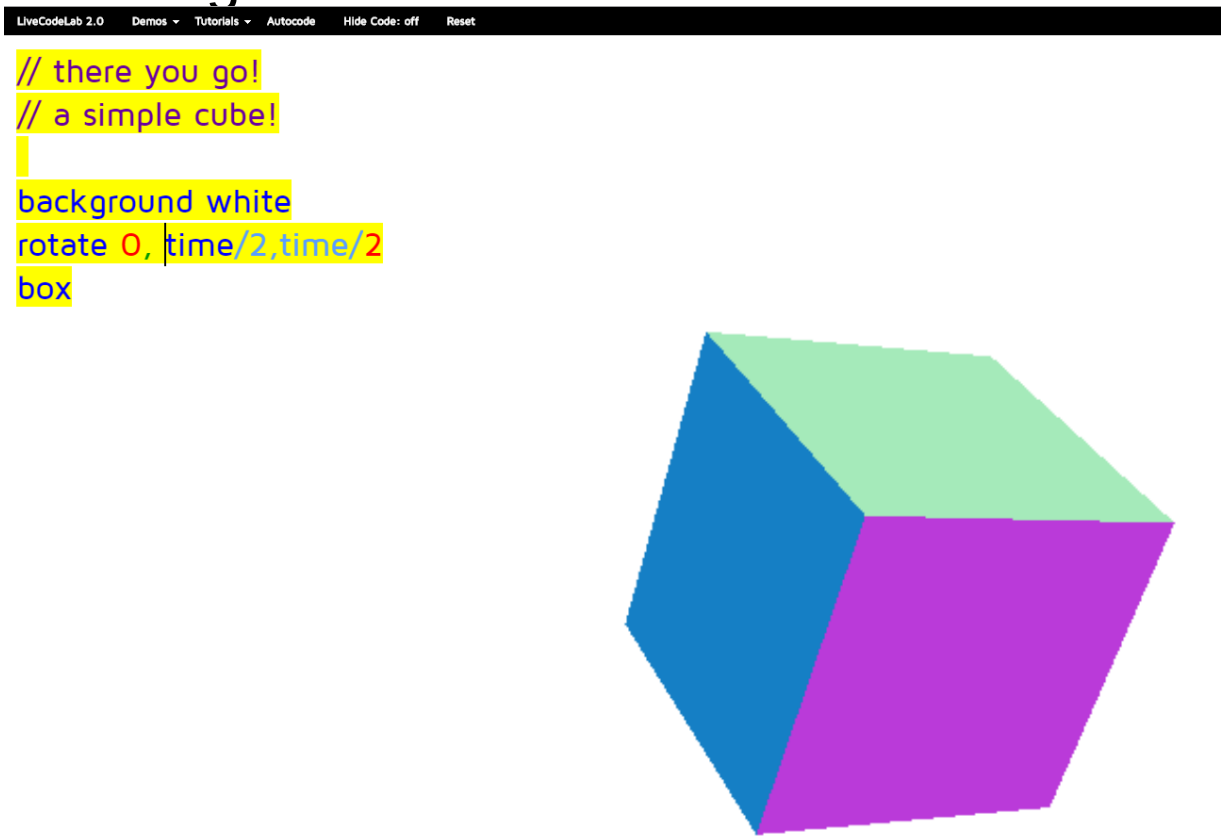
- Try adding different geometries, such as
  - Cylinder
  - Ring
  - Octahedron
  - Torus
  - Others

- The syntax of the geometries have been provided

http://threejs.org/docs/index.html#Manual/Introduction/Creating_a_scene

Future Learning – LiveCodeLab 2.0

- Live coding and lots of cool demonstrations

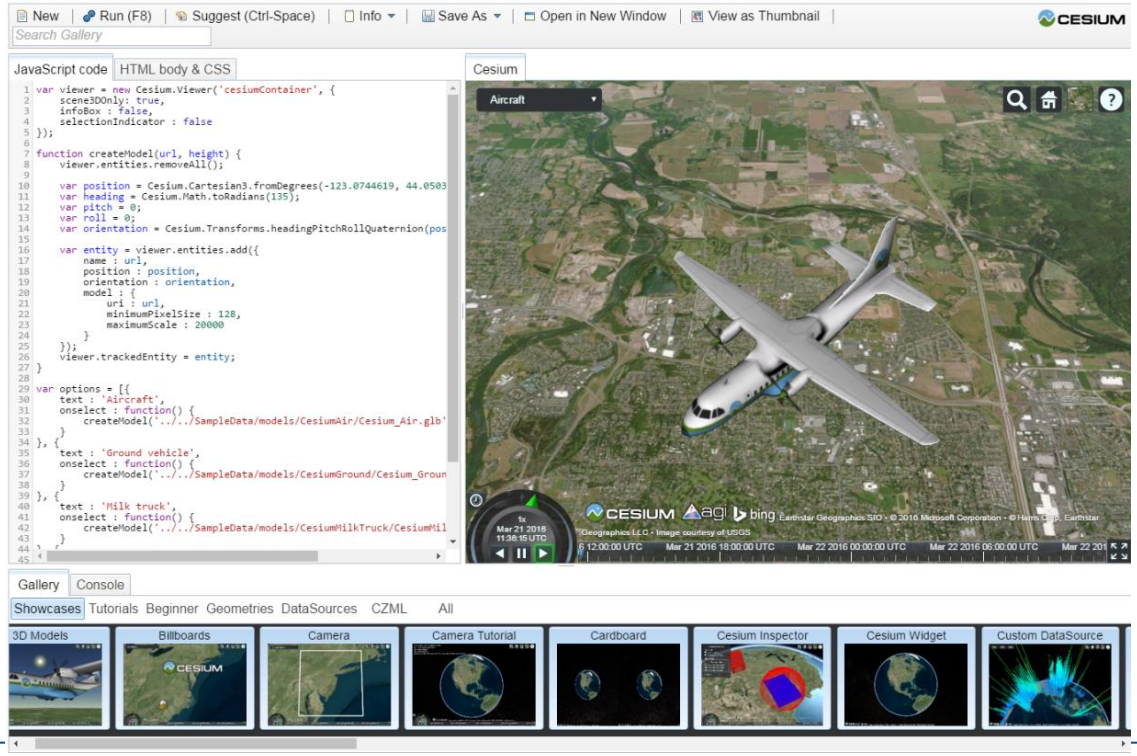


More details: http://livecodelab.net/play/index.html#bookmark=simpleCubeDemo

Session 4:
Cesium Hands-on

Cesium Sandcastle – Live Coding

- Suitable for beginners
  - Easy JavaScript coding
  - Results are visible instantly
- Sandcastle is available on Cesium server
  - No installation required



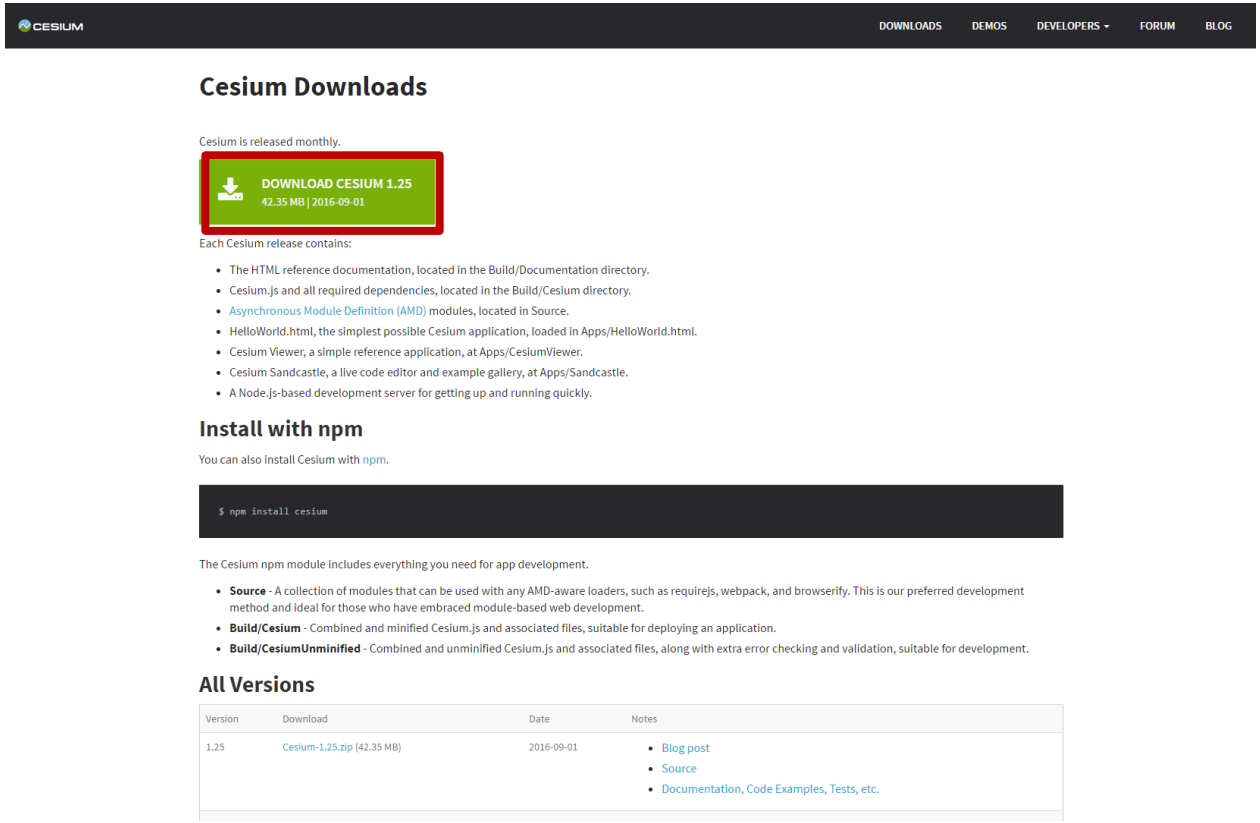
Installing Cesium

- For own application development, it is recommended to use a local installation of Cesium
- Step 1: Install node.js

More details: https://nodejs.org/en/

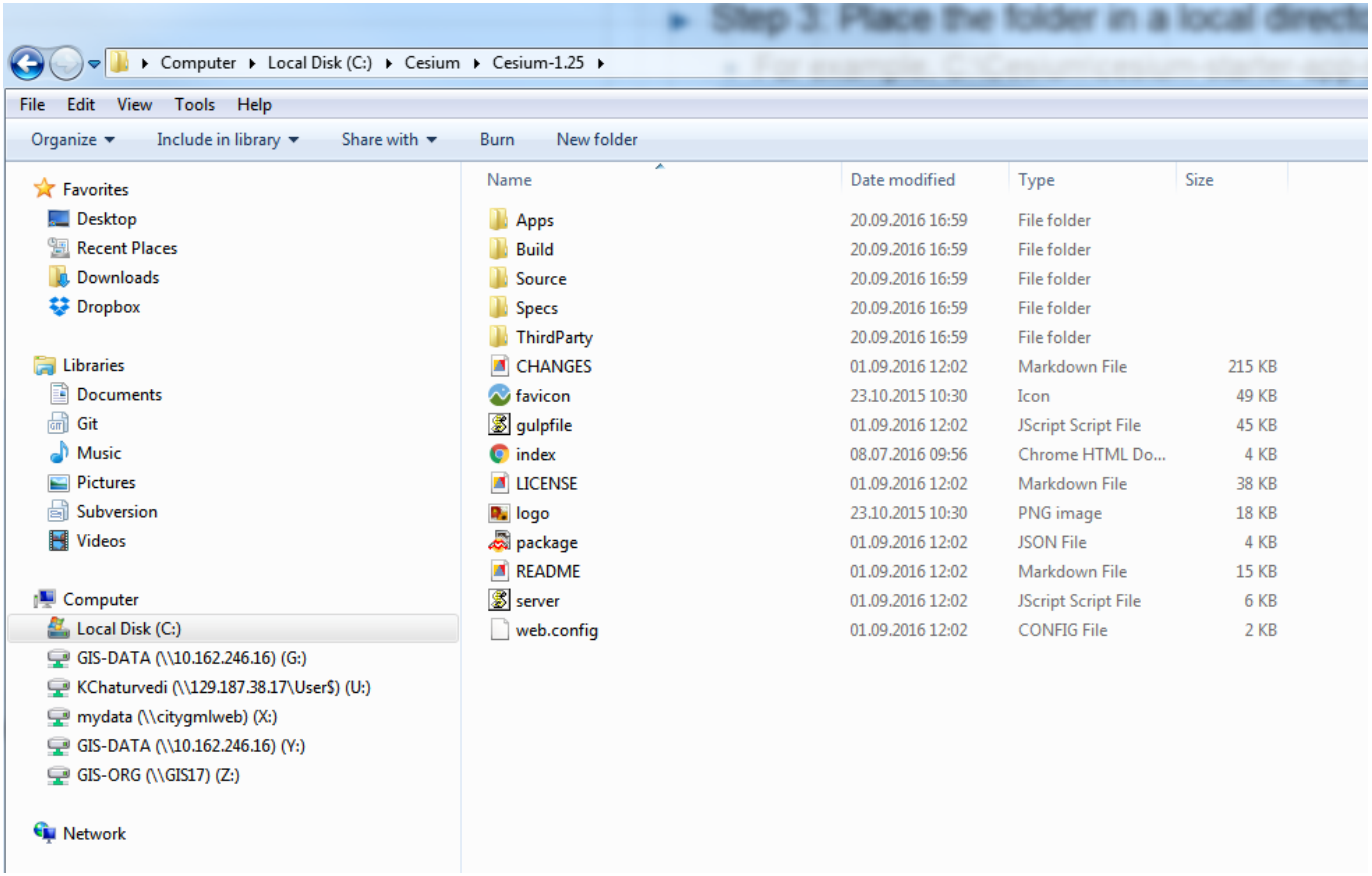
Installing Cesium

- Step 2: Download latest version of Cesium
  https://cesiumjs.org/downloads.html



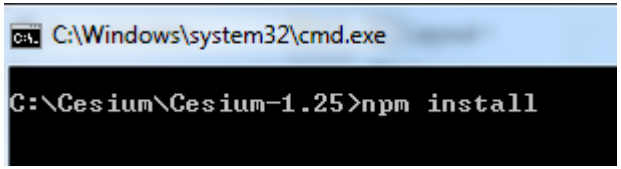
Installing Cesium

- Step 3: Place the folder in a local directory and unzip
  - For example, C:\Cesium\Cesium-1.25

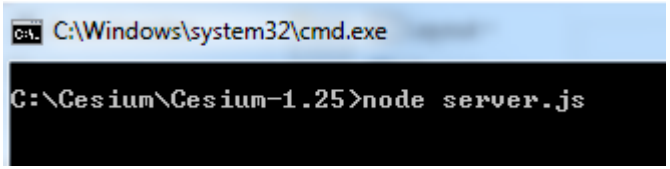


Running Cesium (under Windows)

- Step 1: Open command prompt
- Step 2: Go to C:\Cesium\Cesium-1.25
- Run
  - npm install

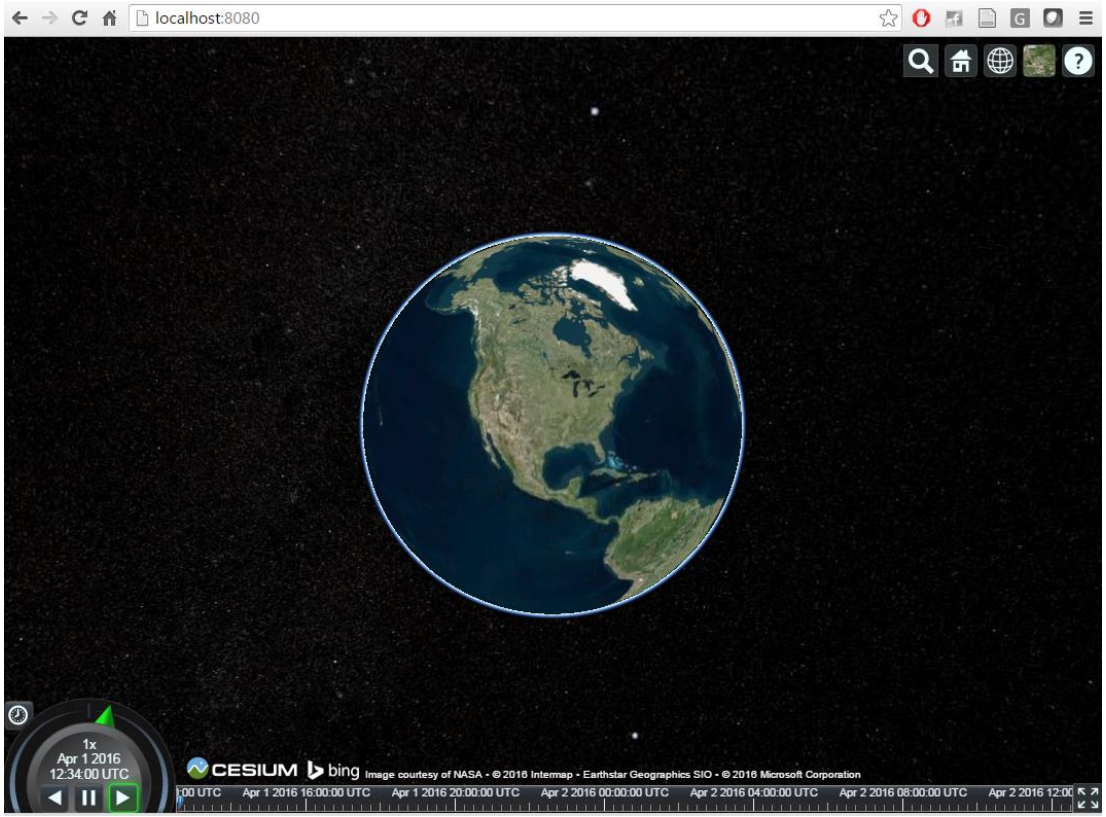


  - node server.js



Running Cesium

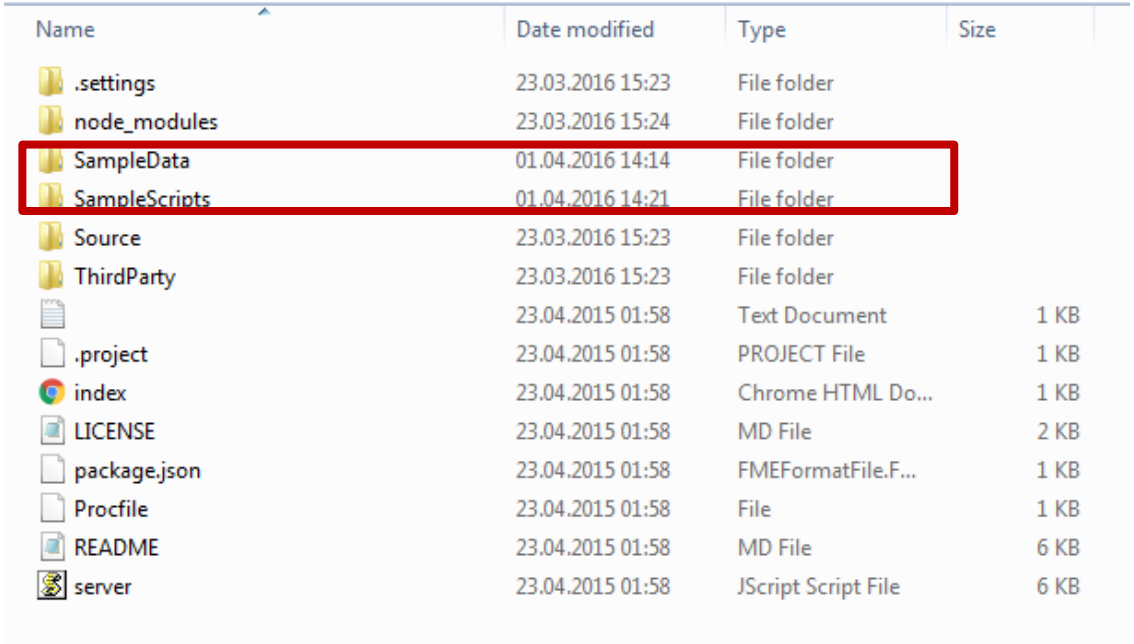
- Step 4: Open a web browser
  - Go to http://localhost:8080 and select HelloWorld.html



- Cesium is up and running!

Working with examples

- Retrieve folders *SampleData* and *SampleScripts* from the location
  www.3dcitydb.org/3dcitydb/fileadmin/TUM_Workshop/
- Copy folders *SampleData* and *SampleScripts* in the Cesium Folder C:\Cesium\cesium-starter-app-master



  - SampleScripts contains example HTML files for test purposes
  - SampleData contains sample data files for loading

Basic Hello World Example

- HelloWorld.html

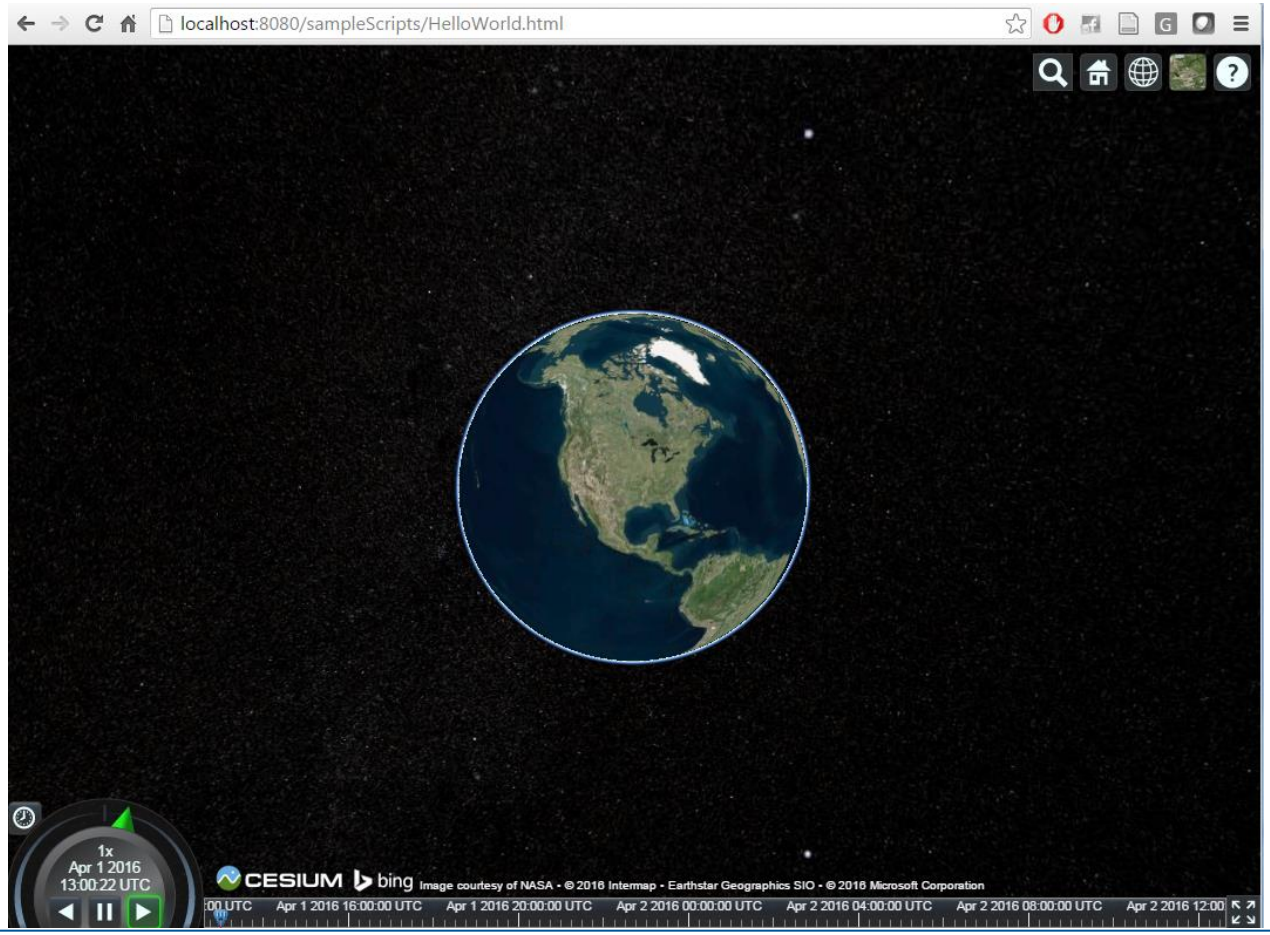
```
<!DOCTYPE html>
<html lang="en">
<head>
  <title>Hello World</title>
  <script src="../ThirdParty/Cesium/Cesium.js"></script>
  <style>
      @import url(../ThirdParty/Cesium/Widgets/widgets.css);
      html, body, #cesiumContainer {
          width: 100%; height: 100%; margin: 0; padding: 0; overflow: hidden;
      }
  </style>
</head>
<body>
  <div id="cesiumContainer"></div>
  <script>
              var viewer = new Cesium.Viewer('cesiumContainer');
  </script>
</body>
</html>
```

Calling Cesium JavaScript

Enabling Cesium Viewer

Basic Hello World Example

- Open HelloWorld.html in the browser,
  - E.g., type http://localhost:8080/sampleScripts/HelloWorld.html



Adding simple geometries

AddingGeometry.html

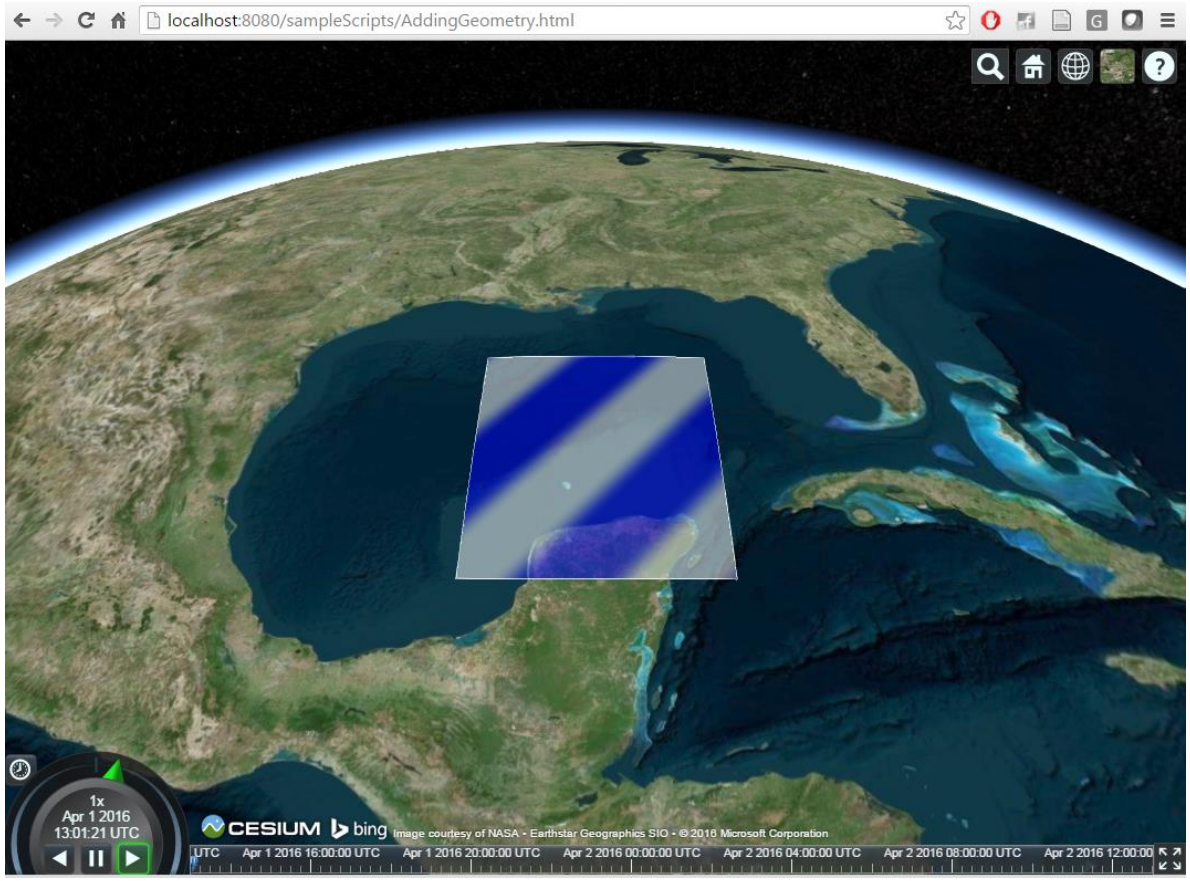
```
<!DOCTYPE html>
<html lang="en">
<head>
  <title>Adding simple geometry</title>
  <script src="../ThirdParty/Cesium/Cesium.js"></script>
  <style>
     @import url(../ThirdParty/Cesium/Widgets/widgets.css);
     html, body, #cesiumContainer {
        width: 100%; height: 100%; margin: 0; padding: 0; overflow: hidden;
     }
  </style>
</head>
<body>
  <div id="cesiumContainer"></div>
  <script>

                var viewer = new Cesium.Viewer('cesiumContainer', { infoBox : false });
                var entities = viewer.entities;

                var stripeMaterial = new Cesium.StripeMaterialProperty({
                                evenColor : Cesium.Color.WHITE.withAlpha(0.5),
                                oddColor : Cesium.Color.BLUE.withAlpha(0.5),
                                repeat : 5.0
                });

                entities.add({
                                rectangle : {
                                                coordinates : Cesium.Rectangle.fromDegrees(-92.0, 20.0, -86.0, 27.0),
                                                outline : true,
                                                outlineColor : Cesium.Color.WHITE,
                                                outlineWidth : 4,
                                                stRotation : Cesium.Math.toRadians(45),
                                                material : stripeMaterial
                                }
                });
                viewer.zoomTo(viewer.entities);
  </script>
</body>
</html>
```

Defining material

Creating simple rectangle

Adding simple geometries

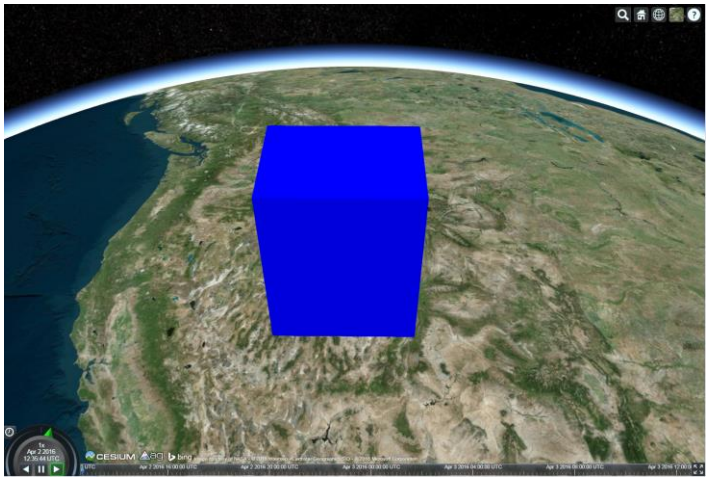
- Open AddingGeometry.html in the browser,
  - E.g., type http://localhost:8080/sampleScripts/AddingGeometry.html

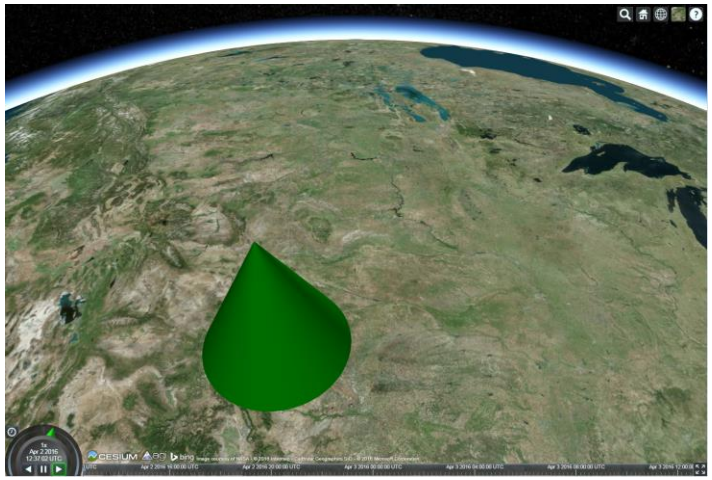


Exercise

- Exercise 1:
  - Change the dimensions and colour of the rectangle

- Exercise 2:
  - Create a new HTML file ‚AddingBox.html', having a Box geometry
  - Create a new HTML file, AddingCone.html' having a cone geometry





Adding simple CZML

AddingCZML.html

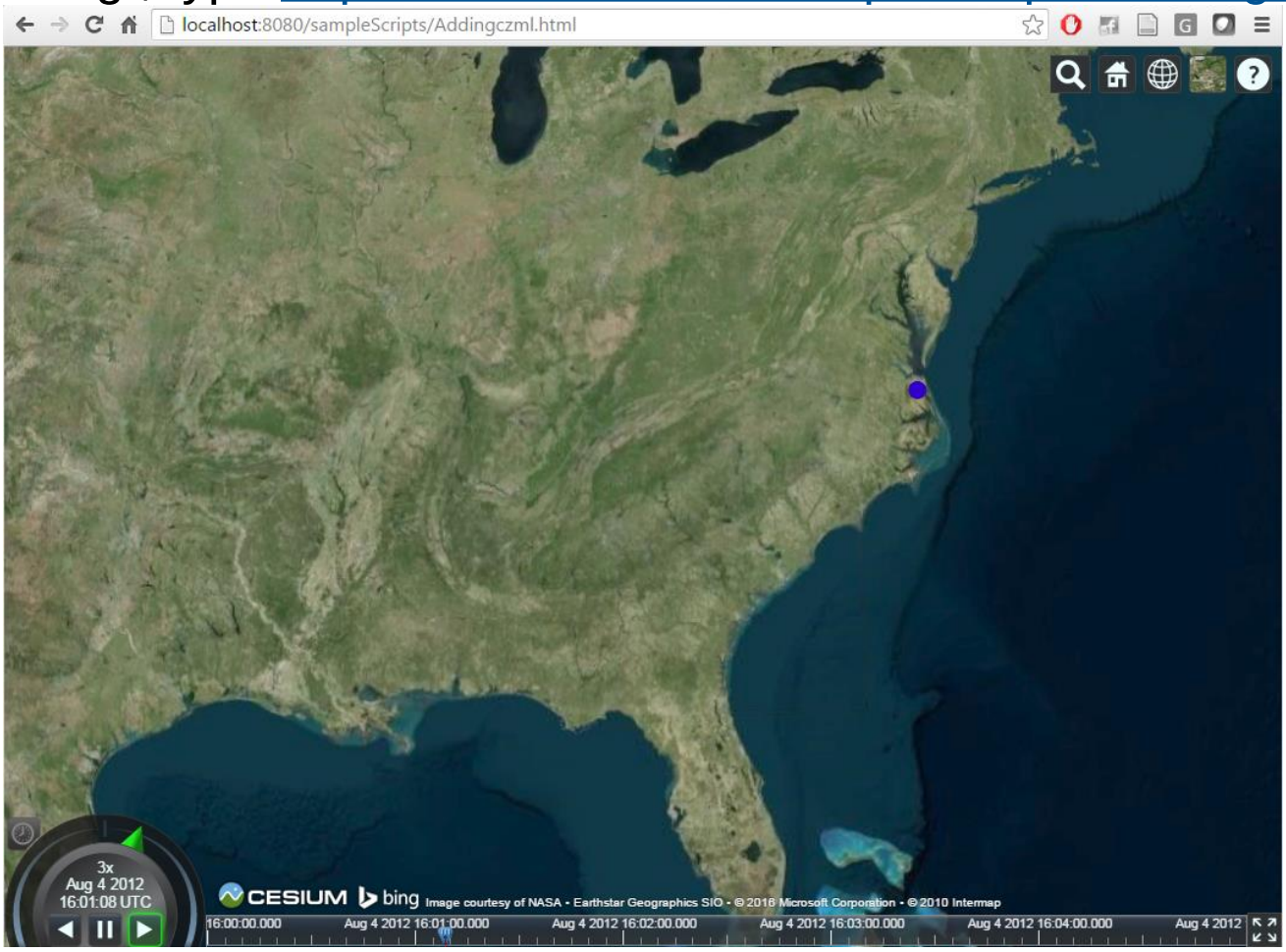
```
<!DOCTYPE html>
.....
<body>
  <div id="cesiumContainer"></div>
  <script>
                    var czml = [
                    {
                    "id" : "document",
                     "name" : "CZML Point - Time Dynamic",
                     "version" : "1.0"
                    }, {
                     "id" : "point",
                     "availability" :"2012-08-04T16:00:00Z/2012-08-04T16:05:00Z",
                     "position" : {
                       "epoch" : "2012-08-04T16:00:00Z",
                      "cartographicDegrees" : [
                                          0,   -70, 20, 150000,
                                          100, -80, 44, 150000,
                                          200, -90, 18, 150000,
                                          300, -98, 52, 150000
                                          ]
                     },
                    "point" : {
                      "color" : {
                        "rgba" : [50, 0, 200, 255]
                       },
                     "outlineColor" : {
                        "rgba" : [200, 0, 20, 20]
                       },
                      "pixelSize" : 15
                    }
                     }
                    ];
     var viewer = new Cesium.Viewer('cesiumContainer');
     viewer.dataSources.add(Cesium.CzmlDataSource.load(czml));
  </script>
</body>
</html>
```

Defining CZML

Adding CZML source

Adding simple CZML

- Open AddingCZML.html in the browser,
  - E.g., type http://localhost:8080/sampleScripts/AddingCZML.html



Exercise

- Can you try adding one more dynamic point moving in parallel to this point?

Adding Datasource - KML

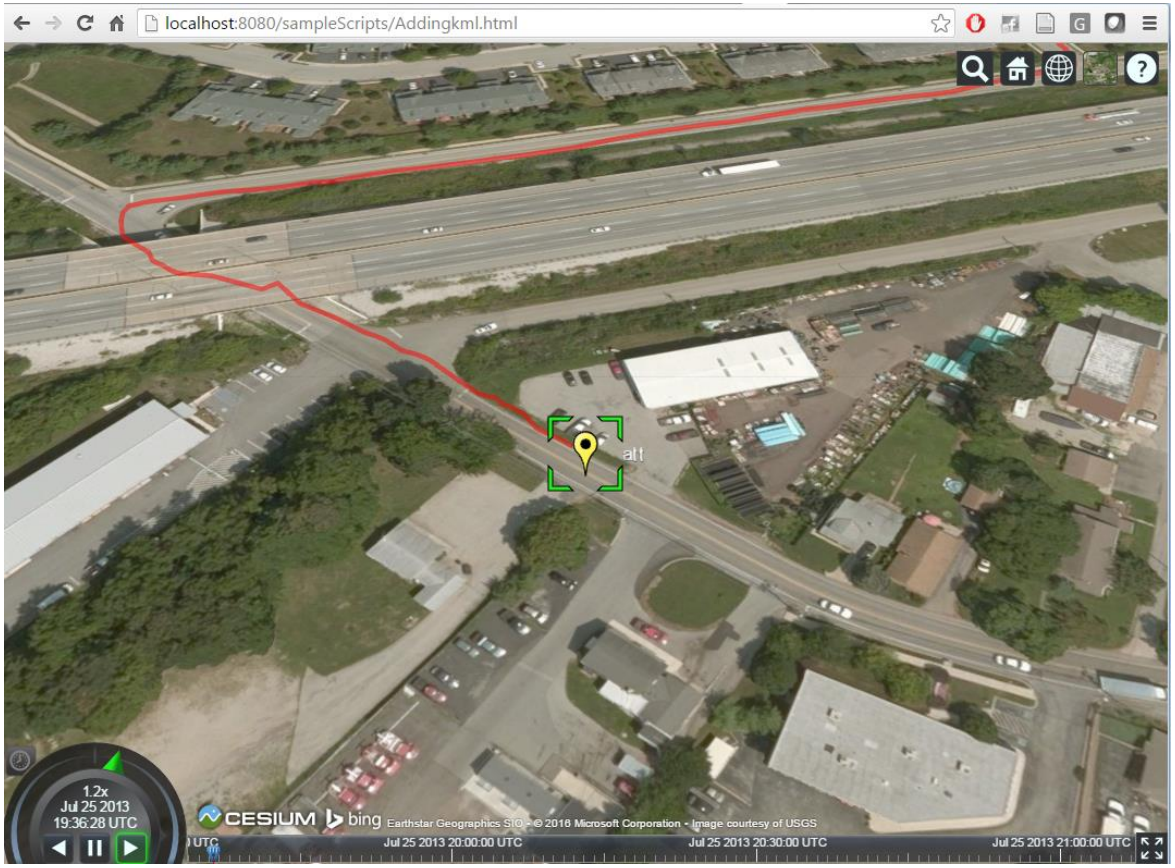
AddingKML.html

```
<!DOCTYPE html>
<html lang="en">
<head>
  <title>Adding KML</title>
  <script src="../ThirdParty/Cesium/Cesium.js"></script>
  <style>
     @import url(../ThirdParty/Cesium/Widgets/widgets.css);
     html, body, #cesiumContainer {
        width: 100%; height: 100%; margin: 0; padding: 0; overflow: hidden;
     }
  </style>
</head>
<body>
  <div id="cesiumContainer"></div>
  <script>

    var viewer = new Cesium.Viewer('cesiumContainer', { infoBox : false });
    var entities = viewer.entities;

    var options = {
       camera : viewer.scene.camera,
       canvas : viewer.scene.canvas
                    };

    viewer.dataSources.add(Cesium.KmlDataSource.load('../SampleData/bikeRide.kml', options)).then(function(dataSource){
          viewer.clock.shouldAnimate = false;
          var rider = dataSource.entities.getById('tour');
          viewer.flyTo(rider).then(function(){
             viewer.trackedEntity = rider;
             viewer.selectedEntity = viewer.trackedEntity;
             viewer.clock.multiplier = 30;
             viewer.clock.shouldAnimate = true;
          });
       });

  </script>
</body>
</html>
```

Adding KML source

Adding Datasource - KML

- Open AddingKML.html in the browser,
  - E.g., type http://localhost:8080/sampleScripts/AddingKML.html



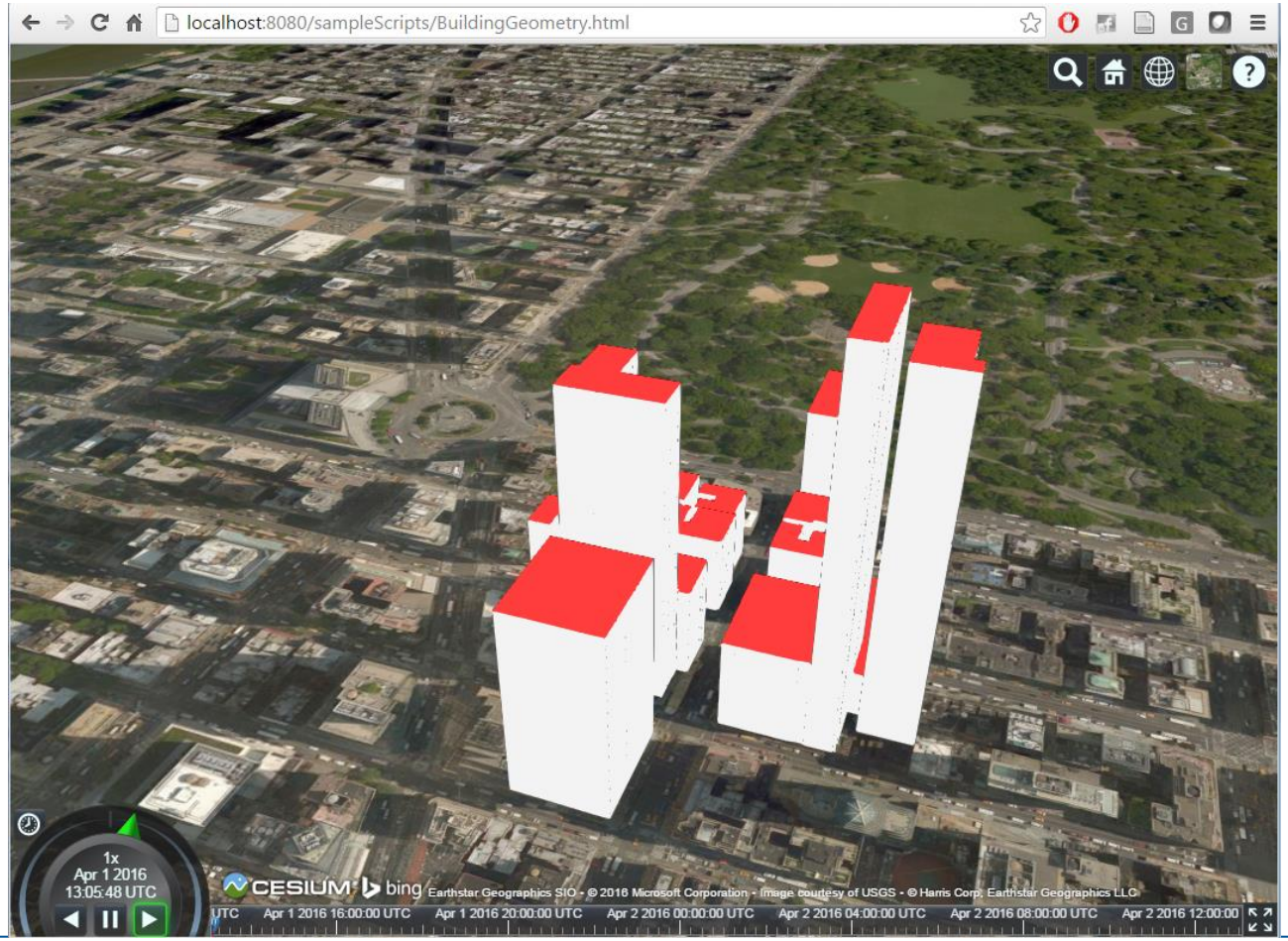
Simple COLLADA Building stored as KMZ file

- BuildingGeometry.html

```
<!DOCTYPE html>
<html lang="en">
<head>
  <title>Adding KMZ</title>
  <script src="../ThirdParty/Cesium/Cesium.js"></script>
  <style>
     @import url(../ThirdParty/Cesium/Widgets/widgets.css);
     html, body, #cesiumContainer {
        width: 100%; height: 100%; margin: 0; padding: 0; overflow: hidden;
     }
  </style>
</head>
<body>
  <div id="cesiumContainer"></div>

  <script>
                    var viewer = new Cesium.Viewer('cesiumContainer');

                     var promise =  viewer.dataSources.add(Cesium.KmlDataSource.load('../SampleData/Building_test_Tile_1_1_geometry.kmz'));
                     viewer.flyTo(promise);
   </script>
</body>
</html>
```

Simple COLLADA Building stored as KMZ file

- Open BuildingGeometry.html in the browser,
  - E.g., type http://localhost:8080/sampleScripts/BuildingGeometry.html



Exercise

- Create a new HTML file ‚AddingKMZ.html', having a Box geometry
  - Load KMZ File *Building_test_Tile_0_0_geometry.kmz* in a similar manner