National Aeronautics and
Space Administration

Web-based Space Mission Visualization Tutorial

AlaSim International 2016

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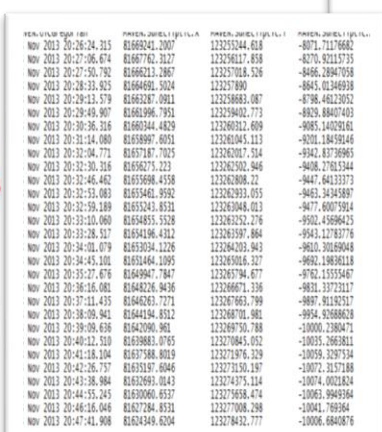
MARSHALL
SPACE FLIGHT CENTER

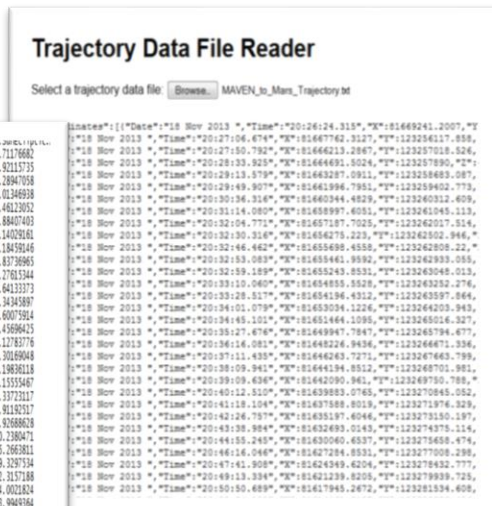
What is Web-based Space Mission Visualization?

- A capability to communicate space mission concepts
  - Interactive simulations that include 3D models of celestial bodies, spacecraft, and orbital trajectories
  - Simulations run natively within a web-browser, i.e., no plug-ins required
- System components:
  - Tutorials that explain how to create web-based mission visualizations
  - Demonstrations that provide reusable code for new mission simulations
  - Free mission design application and code libraries
  - A repository for managing reusable models and simulation code
- Notional workflow:

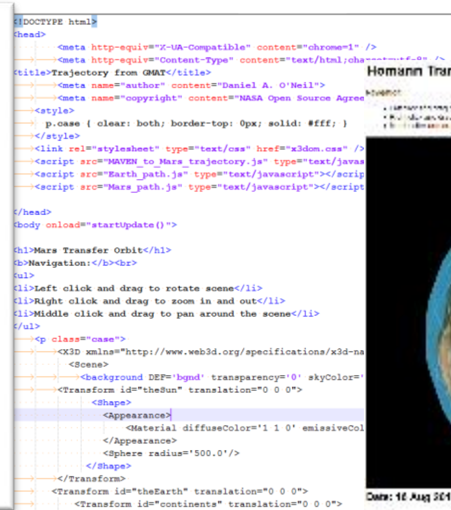
Design Mision with NASA's General Mission Analysis Tool (GMAT)



Export Trajectory Data



Convert to JavaScript Object Notation (JSON)



Integrate with reusable JavaScript & WebGL code

Deploy mission simulation web-page

Web-based Mission Visualization System
Value Propositions

- Improves communication between mission designers and decision makers through interactive mission simulations
  - No downloading of a large desktop application
  - No plug-in required to run the simulation visualizations in a web browser
- Enables cultural transformation from static chart-deck presentations to interactive model-based demonstrations
  - Models embedded in web-pages can be linked to other web-based models and supporting web-based documentation
  - Visualizations can play data-files generated from sophisticated orbital dynamics analysis applications, e.g., General Mission Analysis Tool (GMAT) and Systems Tool Kit (STK) 11
- Provides opportunities to build agency-wide multi-disciplinary teams
  - Orbital dynamists can generate trajectory files with GMAT, STK11, or custom codes
  - Web-app developers use the files to produce interactive mission visualizations
- Engages and educates the public
  - People gain a better understanding of future space missions through the simulations
  - Citizen scientists can publish their web-based mission models
  - A public website provides mission galleries, discussion forums, tutorials, and code repositories

A Tool Kit for Web-based Space Mission Visualization

Modern web-browsers execute JavaScript and WebGL natively, which enables development of embedded simulations.

- **X3dom** – a JavaScript code library that provides the capability to embed X3D scene-graphs in an HTML document
- **glTF** – a 3D file format, developed by Khronos Group, for transmission of models and scenes
- **Cesium** – a free open source digital globe and JavaScript Application Programming Interface provided by Analytical Graphics Inc. (AGI)
- **satellite-js** – a JavaScript code library that implements the Simple General Perturbations (SGP) model for propagating orbits expressed as Two-Line Elements
- **three.js** – a 3D graphics JavaScript library with support for scene-graphs, shapes, shaders, and animation
- **Physics engines** – JavaScript code libraries exist, which enable physics based simulations
- **Game engines** – provide code for the user interface, resource management, icons, models, etc.

http://www.x3dom.org/

https://www.khronos.org/gltf

http://cesiumjs.org/

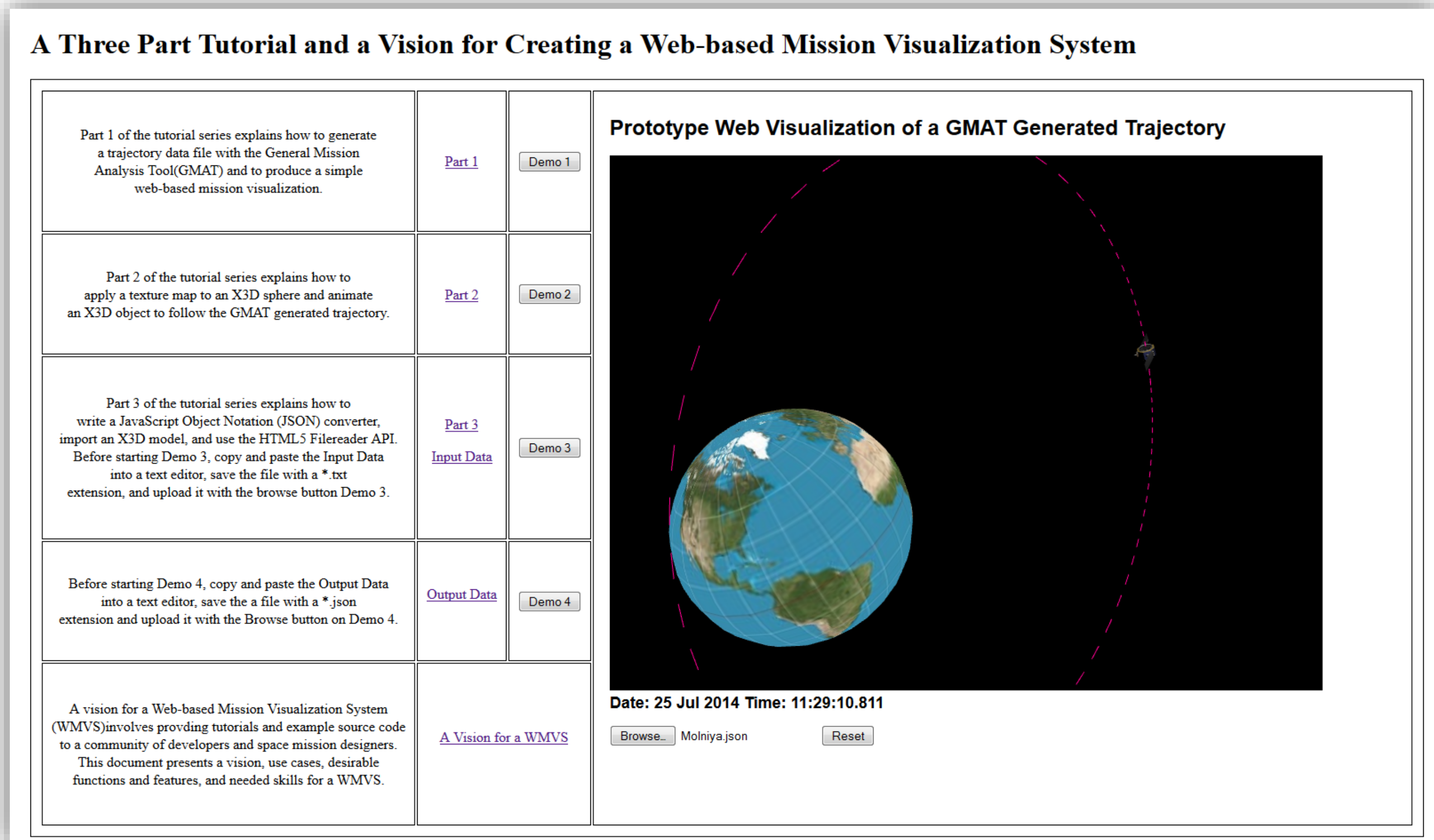
satellite.js v1.2.0

https://github.com/shashwatak/satellite-js

three.js

http://threejs.org/

Tutorials and Demonstrations for X3Dom



http://daoneil.github.io/spacemission/X3Dom/WebMissionVisualizationTutorialSeries.html

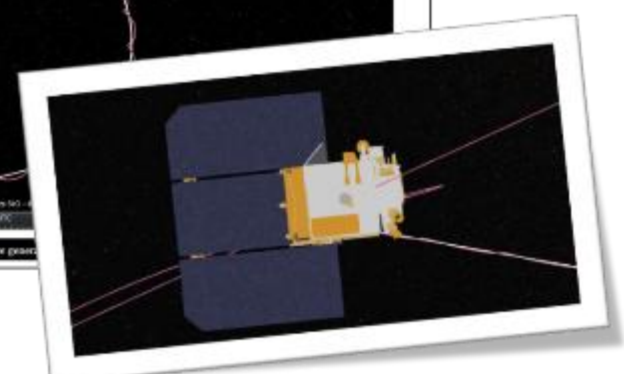
- A Three Part tutorial that explains how to create a web-based mission visualization from trajectory data exported from the General Mission Analysis Tool (GMAT)
- Links lead to the tutorials, buttons activate the demonstrations
- Includes a link to a vision document for a Web-based Space Mission Visualization system

Interactive Earth to Moon Mission Visualization in Cesium

Sat.UTCGregorian	Sat.EarthMJ2000Eq.X	Sat.EarthMJ2000Eq.Y	Sat.EarthMJ2000Eq.Z
22 Jul 2014 11:29:10.811	-137380.198434	75679.8786754	21487.6387519
22 Jul 2014 11:30:10.811	-137394.120769	75653.0884724	21492.7715937
22 Jul 2014 11:33:21.454	-137438.02727	75567.7844716	21509.0290206
22 Jul 2014 11:43:21.330	-137572.907279	75297.5683932	21559.672673
22 Jul 2014 12:13:07.717	-137945.070212	74476.8029406	21705.8661468
22 Jul 2014 13:39:54.803	-138		
22 Jul 2014 16:50:29.706	-139		
22 Jul 2014 19:58:17.654	-137		
22 Jul 2014 22:49:39.159	-134		
23 Jul 2014 01:10:15.710	-130		
23 Jul 2014 03:15:24.444	-126		
23 Jul 2014 05:06:47.357	-121		
23 Jul 2014 06:46:08.345	-115		
23 Jul 2014 08:14:52.984	-110		
23 Jul 2014 09:34:12.984	-104		
23 Jul 2014 10:45:09.816	-989		
23 Jul 2014 11:48:37.120	-932		

"	2014-07-22T	11:29:11Z",	-137380000,	21487600,	75679900,
"	2014-07-22T	11:30:11Z",	-137394000,	21492800,	75653100,
"	2014-07-22T	11:33:21Z",	-137438000,	21509000,	75567800,
"	2014-07-22T	11:43:21Z",	-137573000,	21559700,	75297600,
"	2014-07-22T	12:13:08Z",	-137945000,	21705900,	74476800,
"	2014-07-22T	13:39:55Z",	-138776000,	22092100,	71948900,
"	2014-07-22T	16:50:30Z",	-139253000,	22724900,	65710500,
"	2014-07-22T	19:58:18Z",	-137836000,	23040700,	58673800,
"	2014-07-22T	22:49:39Z",	-134793000,	23037000,	51508000,
"	2014-07-23T	01:10:16Z",	-130940000,	22802600,	45108000,
"	2014-07-23T	03:15:24Z",	-126382000,	22397700,	39022600,
"	2014-07-23T	05:06:4			
"	2014-07-23T	06:46:0			
"	2014-07-23T	08:14:5			
"	2014-07-23T	09:34:1			
"	2014-07-23T	10:45:1			

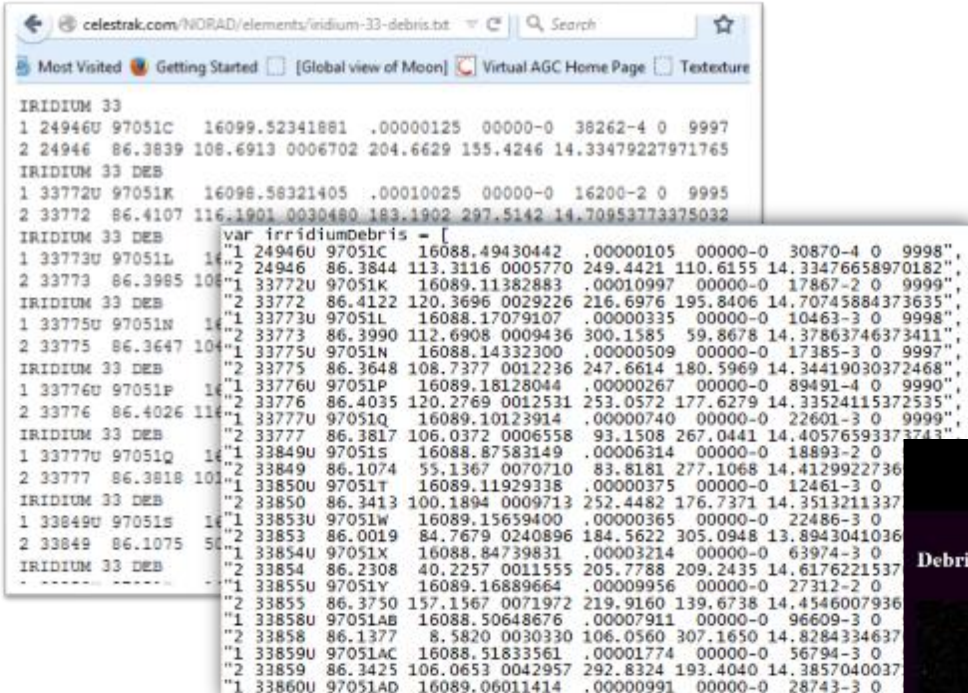
- Trajectory data generated from a GMAT tutorial
- Converted to a JavaScript string variable with Excel



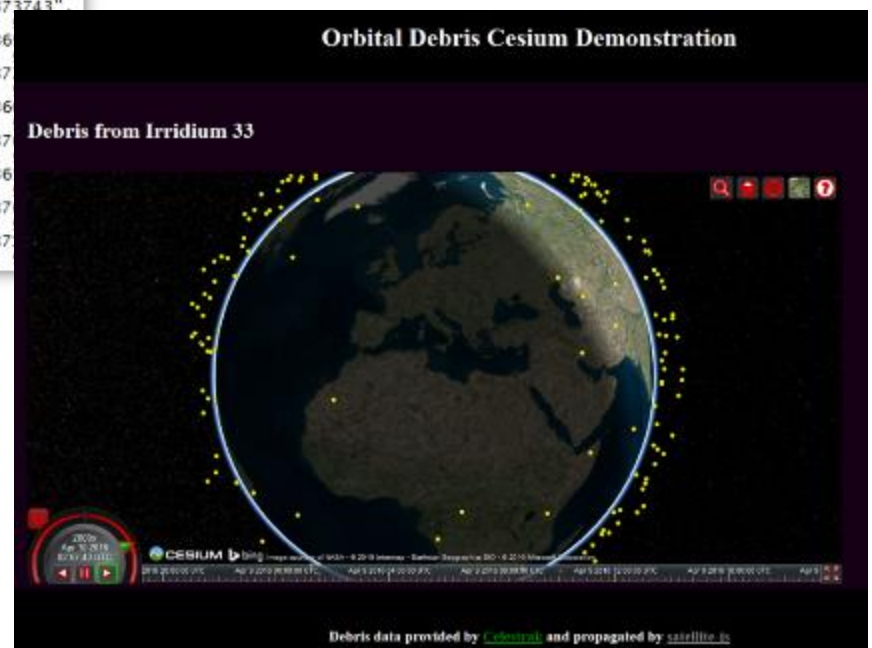
- A lunar probe trajectory and Moon's orbit depicted in Cesium
- Buttons provide different viewpoints for the probe, Moon, Earth, and the big picture

http://daoneil.github.io/spacemission/Apps/EarthToMoon_Demo.html

Orbital Debris Propagation with Satellite-js and Visualized in Cesium



- Two Line Element (TLE) data provided by Celestrak
- Data converted to a JavaScript string variable with Excel
- Positions propagated via Satellite-js

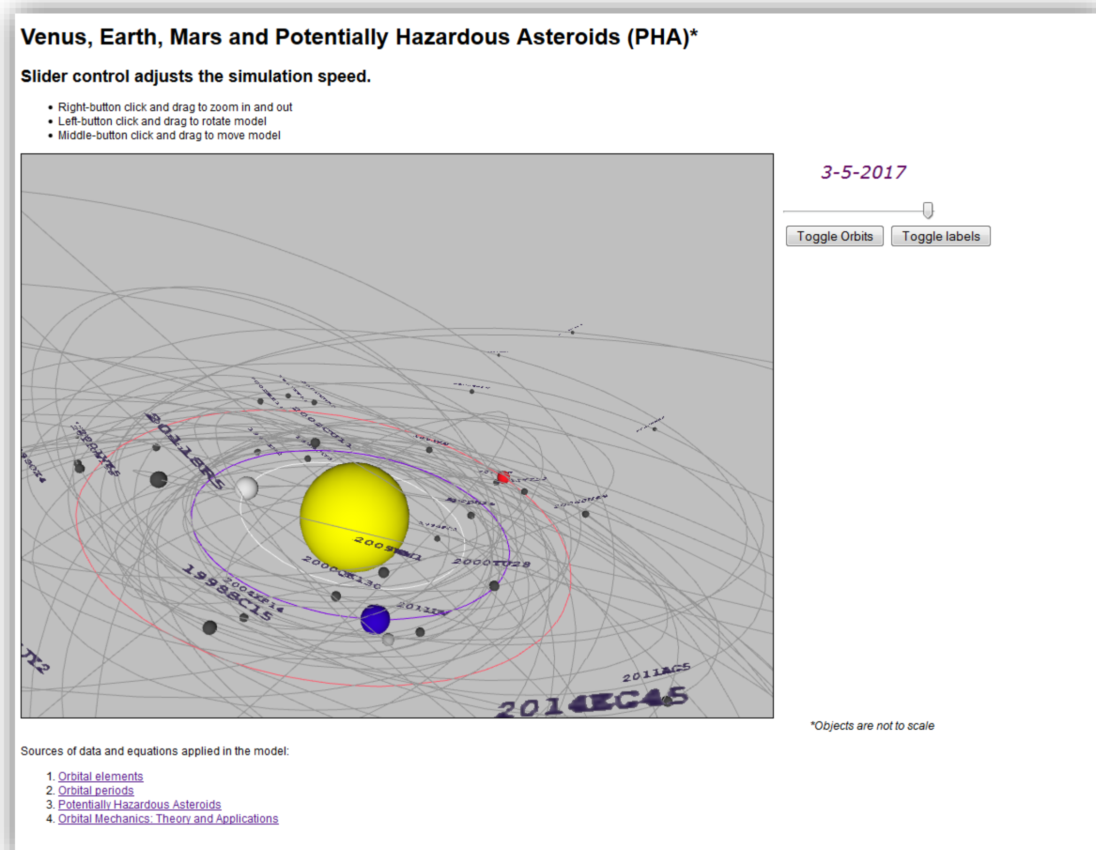


- Two Line Element set
  https://en.wikipedia.org/wiki/Two-line_element_set
- Celestrak
  http://www.celestrak.com/NORAD/elements/
- Satellite-js
  https://github.com/shashwatak/satellite-js
- Simple General Perturbations (SGP) Model
  https://en.wikipedia.org/wiki/Simplified_perturbations_models

http://daoneil.github.io/spacemission/Apps/Cesium_with_SGP.html

Potentially Hazardous Asteroids Visualization with an embedded orbital propagator

- Data provided by the JPL Near Earth Objects Program Office
- Orbital propagator based on a flow-chart provided in Tom Logsdon's book "Orbital Mechanics: Theory and Applications
- Developed with the X3Dom code library



http://daoneil.github.io/spacemission/X3Dom/InnerSolarSystem.html

Future Work and Conclusions

- Established a Public Repository to Share Mission Files
  - Publish the tutorials and demonstration code to potential development partners around the agency and the general public
  - Provide a repository for agency mission planners and citizen scientists to share General Mission Analysis Tool scripts and Web-based Mission Visualization code
  - Establish discussion forums so people can share ideas about converting trajectory files into interactive web-based simulations

- Continue development of demonstrations and tutorials
  - Create five or six web-based mission visualizations to demonstrate various types of missions, e.g., LEO, GEO, Moon, Asteroids, Mars, etc.
  - Write tutorials related to system models and visualization control widgets

- Facilitate an open-source development project to implement the Web-based Space Mission Visualization System
  - Seek sponsorship for open-source development project, e.g., TopCoder
  - Demonstrate capabilities to space system development projects

- Invitation to contribute code: If you are interested, please contact *Daniel A. O’Neil*, daniel.a.oneil@nasa.gov