

National Aeronautics and
Space Administration



Web-based Space Mission Visualization Tutorial

AlaSim International 2016

Daniel A. O'Neil

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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

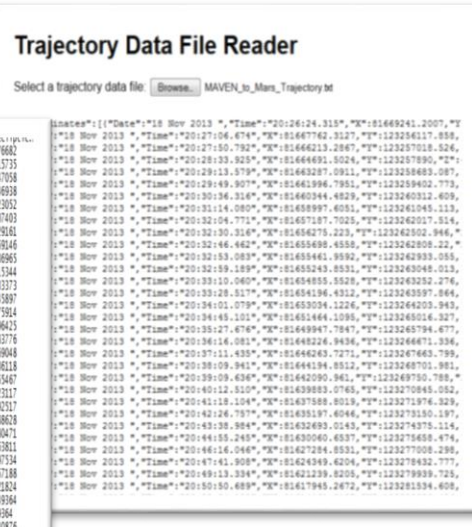
• Notional workflow:



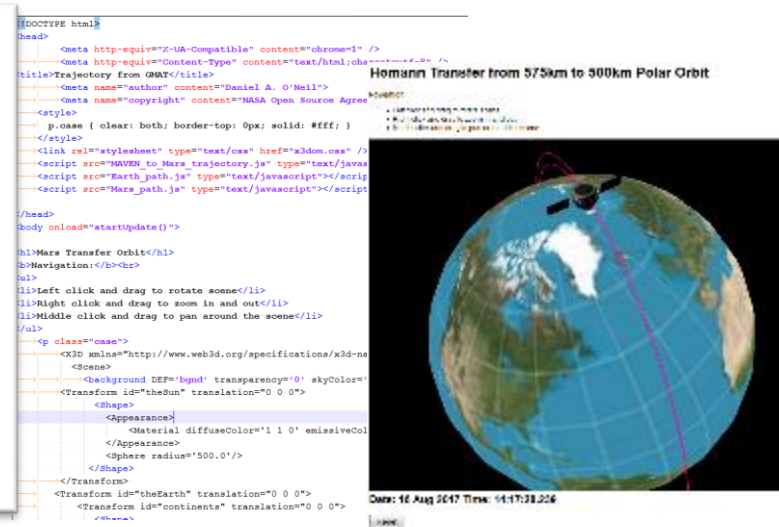
Design Mission with NASA's General Mission Analysis Tool (GMAT)

TIME_VECT	TIME_VECT	TIME_VECT	TIME_VECT
Nov 2013 20:28:24.315	8166621.1007	12325244.818	-8071.7116682
Nov 2013 20:27:06.674	81667762.3127	123256117.858	-8270.8215735
Nov 2013 20:27:50.792	81666213.2867	123257018.526	-8486.2884758
Nov 2013 20:28:35.925	81664691.3024	123257899	-8645.01346938
Nov 2013 20:29:13.579	81663287.0911	123258683.087	-8798.48120552
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Nov 2013 20:31:14.080	81658997.0951	123260845.113	-9201.18459146
Nov 2013 20:32:04.771	81657187.7025	123262017.514	-9342.83736965
Nov 2013 20:32:30.216	81656275.1223	123262912.946	-9406.2761544
Nov 2013 20:32:46.462	81655998.4558	123262908.22	-9447.64133773
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Nov 2013 20:35:27.874	81649947.7847	123265794.877	-9702.1555487
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Nov 2013 20:37:11.435	81646763.7271	123267693.789	-9827.8182517
Nov 2013 20:38:09.941	81644294.8512	123268701.981	-9954.5688628
Nov 2013 20:39:09.636	81642096.961	123269750.788	-10000.2388471
Nov 2013 20:40:12.510	81639883.0765	123270845.052	-10053.2683811
Nov 2013 20:41:18.104	81637588.8019	123271976.329	-10099.3297334
Nov 2013 20:42:26.757	81635319.8046	123273181.187	-10073.7137886
Nov 2013 20:43:38.984	81632993.0143	123274375.114	-10074.001824
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Nov 2013 20:47:41.908	81624949.6204	123278433.777	-10006.68076

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.



<https://www.khronos.org/glTF>



<http://cesiumjs.org/>

satellite.js v1.2.0

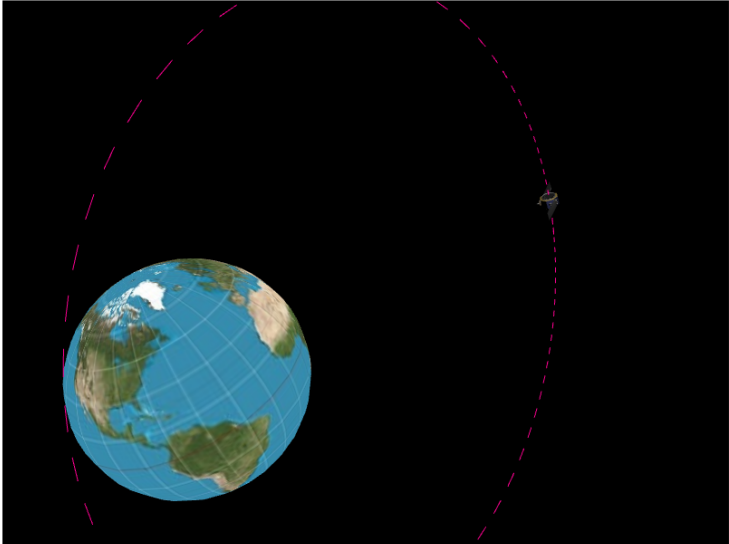
<https://github.com/shashwatak/satellite-js>

three.js

<http://threejs.org/>

Tutorials and Demonstrations for X3Dom

A Three Part Tutorial and a Vision for Creating a Web-based Mission Visualization System

<p>Part 1 of the tutorial series explains how to generate a trajectory data file with the General Mission Analysis Tool(GMAT) and to produce a simple web-based mission visualization.</p>	Part 1	<input type="button" value="Demo 1"/>	<h3>Prototype Web Visualization of a GMAT Generated Trajectory</h3>  <p>Date: 25 Jul 2014 Time: 11:29:10.811</p> <input type="button" value="Browse..."/> Molniya.json <input type="button" value="Reset"/>
<p>Part 2 of the tutorial series explains how to apply a texture map to an X3D sphere and animate an X3D object to follow the GMAT generated trajectory.</p>	Part 2	<input type="button" value="Demo 2"/>	
<p>Part 3 of the tutorial series explains how to write a JavaScript Object Notation (JSON) converter, import an X3D model, and use the HTML5 FileReader API. Before starting Demo 3, copy and paste the Input Data into a text editor, save the file with a *.txt extension, and upload it with the browse button Demo 3.</p>	Part 3 Input Data	<input type="button" value="Demo 3"/>	
<p>Before starting Demo 4, copy and paste the Output Data into a text editor, save the a file with a *.json extension and upload it with the Browse button on Demo 4.</p>	Output Data	<input type="button" value="Demo 4"/>	
<p>A vision for a Web-based Mission Visualization System (WMVS) involves providing tutorials and example source code to a community of developers and space mission designers. This document presents a vision, use cases, desirable functions and features, and needed skills for a WMVS.</p>	A Vision for a WMVS		

<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

Year-Month-Day	Time (Z)	X (Z)	Y (Z)	Z (Z)
2014-07-22	11:29:11 Z"	-137380000,	21487600,	75679900,
2014-07-22	11:30:11 Z"	-137394000,	21492800,	75653100,
2014-07-22	11:33:21 Z"	-137438000,	21509000,	75567800,
2014-07-22	11:43:21 Z"	-137573000,	21559700,	75297600,
2014-07-22	12:13:08 Z"	-137945000,	21705900,	74476800,
2014-07-22	13:39:55 Z"	-138776000,	22092100,	71948900,
2014-07-22	16:50:30 Z"	-139253000,	22724900,	65710500,
2014-07-22	19:58:18 Z"	-137836000,	23040700,	58673800,
2014-07-22	22:49:39 Z"	-134793000,	23037000,	51508000,
2014-07-23	01:10:16 Z"	-130940000,	22802600,	45108000,
2014-07-23	03:15:24 Z"	-126382000,	22397700,	39022600,
2014-07-23	05:06:40 Z"	-122000000,	21900000,	32000000,
2014-07-23	06:46:00 Z"	-117000000,	21400000,	25000000,
2014-07-23	08:14:50 Z"	-112000000,	20900000,	18000000,
2014-07-23	09:34:10 Z"	-107000000,	20400000,	11000000,
2014-07-23	10:45:10 Z"	-102000000,	19900000,	4000000,

- 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

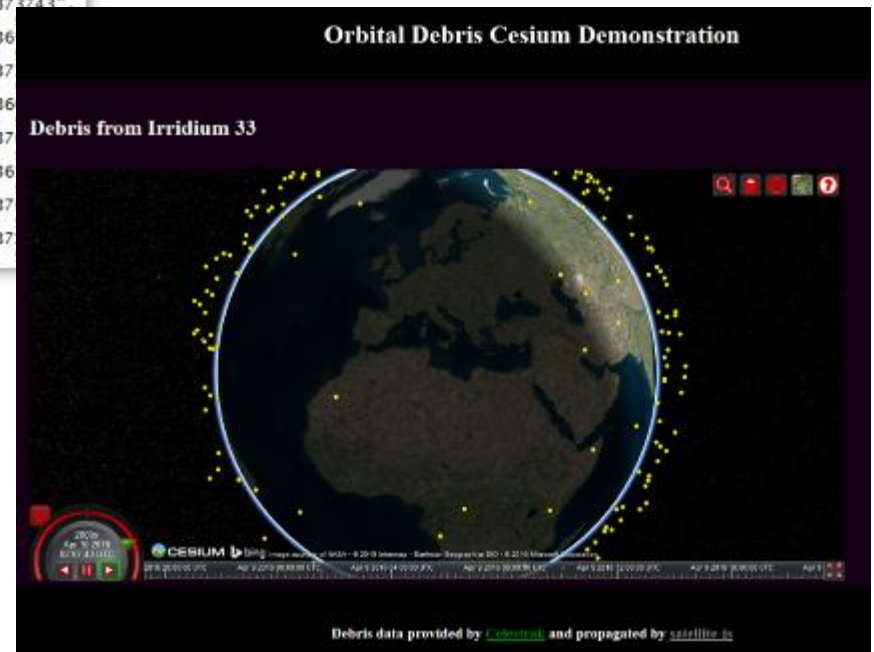


http://daoneil.github.io/spacemission/Apps/EarthToMoon_Demo.html

Orbital Debris Propagation with Satellite-js and Visualized in Cesium

```
celestak.com/NORAD/elements/iridium-33-debris.txt
IRIDIUM 33
1 24946U 97051C 16099.52341881 .00000125 00000-0 38262-4 0 9997
2 24946 86.3839 108.6913 0006702 204.6629 155.4246 14.33479227971765
IRIDIUM 33 DEB
1 33772U 97051K 16098.58321405 .00010025 00000-0 16200-2 0 9995
2 33772 86.4107 116.1901 0030480 183.1902 297.5142 14.70953773375032
IRIDIUM 33 DEB
1 33773U 97051L 16088.49430442 .00000105 00000-0 30870-4 0 9998"
2 24946 86.3844 113.3116 0005770 249.4421 110.6155 14.33476658970182"
2 33773 86.3985 108.7377 0012236 247.6614 180.5969 14.34419030372468"
IRIDIUM 33 DEB
1 33772U 97051K 16089.11382883 .00010997 00000-0 17867-2 0 9999"
2 33772 86.4122 120.3696 0029226 216.6976 195.8406 14.70745884373635"
IRIDIUM 33 DEB
1 33773U 97051L 16088.17079107 .00000335 00000-0 10463-3 0 9998"
2 33773 86.3990 112.6908 0009436 300.1585 59.8678 14.37863746373411"
IRIDIUM 33 DEB
1 33775U 97051N 16088.14332300 .00000509 00000-0 17385-3 0 9997"
2 33775 86.3647 108.7377 0012236 247.6614 180.5969 14.34419030372468"
IRIDIUM 33 DEB
1 33776U 97051P 16089.18128044 .00000267 00000-0 89491-4 0 9990"
2 33776 86.4035 120.2769 0012531 253.0572 177.6279 14.33524115372535"
IRIDIUM 33 DEB
1 33777U 97051Q 16089.10123914 .00000740 00000-0 22601-3 0 9999"
2 33777 86.3817 106.0372 0006558 93.1508 267.0441 14.40576593373743"
IRIDIUM 33 DEB
1 33849U 97051S 16088.87583149 .00006314 00000-0 18893-2 0
2 33849 86.1074 55.1367 0070710 83.8181 277.1068 14.4129922736
IRIDIUM 33 DEB
1 33850U 97051T 16089.11929338 .00000375 00000-0 12461-3 0
2 33850 86.3413 100.1894 0009713 252.4482 176.7371 14.3513211337
IRIDIUM 33 DEB
1 33849U 97051S 16089.15659400 .00000365 00000-0 22486-3 0
2 33853 86.0019 84.7679 0240896 184.5622 305.0948 13.8943041036
IRIDIUM 33 DEB
1 33854U 97051X 16088.84739831 .00003214 00000-0 63974-3 0
2 33854 86.2308 40.2257 0011555 205.7788 209.2435 14.6176221537
IRIDIUM 33 DEB
1 33855U 97051Y 16089.16889664 .00009956 00000-0 27312-2 0
2 33855 86.3750 157.1567 0071972 219.9160 139.6738 14.4546007936
IRIDIUM 33 DEB
1 33858U 97051AB 16088.50648676 .00007911 00000-0 96609-3 0
2 33858 86.1377 8.5820 0030330 106.0560 307.1650 14.8284334637
IRIDIUM 33 DEB
1 33859U 97051AC 16088.51833561 .00001774 00000-0 56794-3 0
2 33859 86.3425 106.0653 0042957 292.8324 193.4040 14.3857040037
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1 33860U 97051AD 16089.06011414 .00000991 00000-0 28743-3 0
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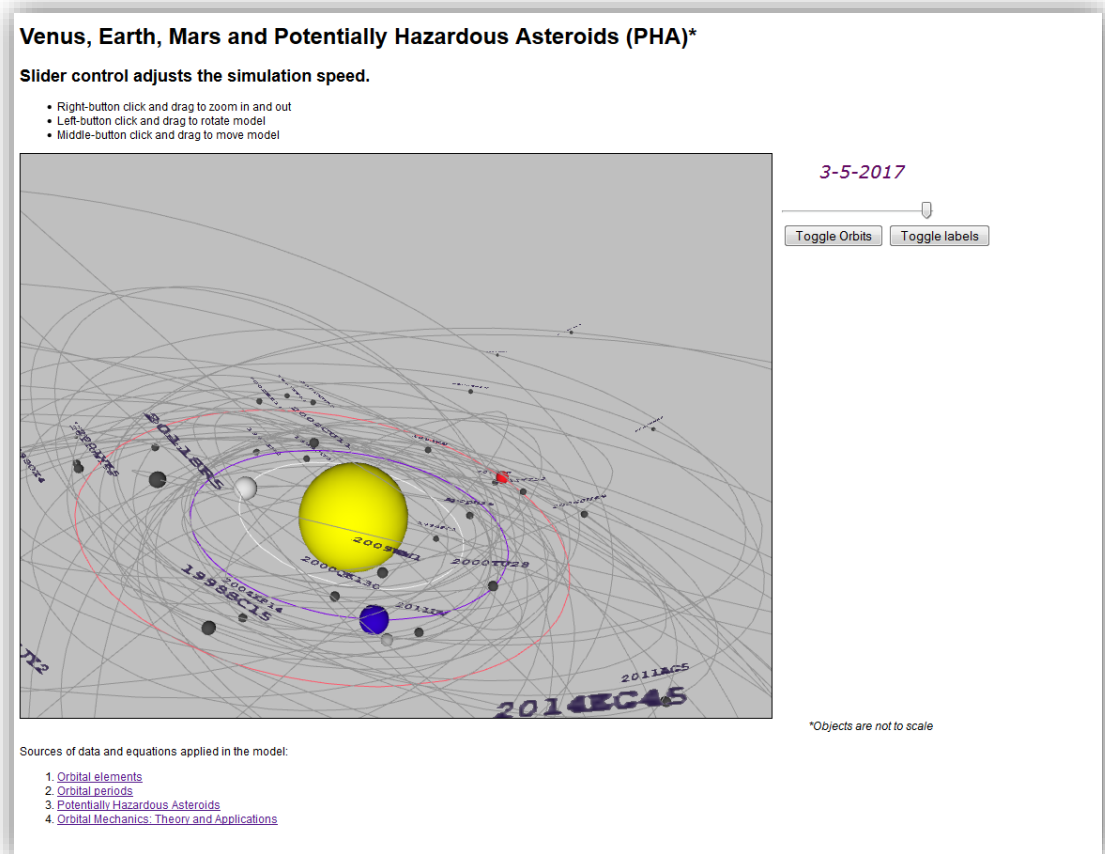
- Two Line Element (TLE) data provided by Celestrak
- Data converted to a JavaScript string variable with Excel
- Positions propagated via Satellite-js



- 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

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