

# Web-based Space Mission Visualization Tutorial

AlaSim International 2016

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National Aeronautics and  
Space Administration



**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 (UTC)	TIME (GMT)	TIME (GMT)	TIME (GMT)
Nov 2013 20:26:24.315	8166821.007	12325234.458	-8071.7116682
Nov 2013 20:27:06.674	81667762.3127	123256117.858	-8270.9215735
Nov 2013 20:27:50.792	8166623.1867	123257018.526	-8466.28447058
Nov 2013 20:28:35.792	81664691.3024	123257989	-8645.01346938
Nov 2013 20:29:15.579	81663287.9911	123258883.087	-8798.4612051
Nov 2013 20:29:48.907	81661996.7951	123259402.773	-8929.8847403
Nov 2013 20:30:36.316	81660344.4829	123260312.409	-9085.18402816
Nov 2013 20:31:14.080	81658997.8051	123261045.113	-9201.18459146
Nov 2013 20:32:04.771	81657187.7025	123262087.534	-9342.83736965
Nov 2013 20:32:50.316	81655675.123	123262902.446	-9406.781534
Nov 2013 20:33:40.462	81653996.4558	123263608.22	-9447.6413373
Nov 2013 20:34:31.081	81652401.8992	123264263.055	-9463.3436887
Nov 2013 20:35:19.189	81650843.8531	123264948.013	-9477.69075914
Nov 2013 20:36:10.060	81649355.8528	123265625.276	-9502.4589425
Nov 2013 20:36:58.517	81647896.4312	123266297.884	-9543.1278776
Nov 2013 20:37:40.079	81646304.1226	123266953.943	-9610.30169048
Nov 2013 20:38:24.101	81644744.1095	123267601.327	-9662.19836118
Nov 2013 20:39:07.874	81643047.7847	123268254.877	-9702.1555487
Nov 2013 20:39:46.102	81641326.9436	123268901.356	-9831.3373117
Nov 2013 20:40:21.113	81639683.7271	123269547.799	-9897.8182517
Nov 2013 20:40:59.941	81644194.8512	123270191.981	-9954.6868628
Nov 2013 20:41:39.636	81642090.361	123270837.788	-10000.2380471
Nov 2013 20:42:12.510	81639883.0765	123271484.052	-10035.205811
Nov 2013 20:42:48.104	81637588.8019	123272136.329	-10059.3287534
Nov 2013 20:43:26.757	81635379.5046	123272791.147	-10073.7137848
Nov 2013 20:44:03.384	81632993.0243	123273437.114	-10074.002824
Nov 2013 20:44:35.284	81630600.6537	123274058.474	-10063.994918
Nov 2013 20:45:06.044	81628278.8531	123274678.298	-10041.769364
Nov 2013 20:45:41.918	81625949.6204	123275283.777	-10006.684076

Export Trajectory Data

## Trajectory Data File Reader

Select a trajectory data file:  MAVEN\_to\_Mars\_Trajectory.MT

```
[{"Date": "18 Nov 2013", "Time": "20:26:24.315", "X": 81668241.007, "Y": 12325234.458, "Z": -8071.7116682}, {"Date": "18 Nov 2013", "Time": "20:27:06.674", "X": 81666231.867, "Y": 123256117.858, "Z": -8270.9215735}, {"Date": "18 Nov 2013", "Time": "20:27:50.792", "X": 81664691.3024, "Y": 123257018.526, "Z": -8466.28447058}, {"Date": "18 Nov 2013", "Time": "20:28:35.792", "X": 81663287.9911, "Y": 123257989, "Z": -8645.01346938}, {"Date": "18 Nov 2013", "Time": "20:29:15.579", "X": 81661996.7951, "Y": 123258883.087, "Z": -8798.4612051}, {"Date": "18 Nov 2013", "Time": "20:29:48.907", "X": 81660344.4829, "Y": 123259402.773, "Z": -8929.8847403}, {"Date": "18 Nov 2013", "Time": "20:30:36.316", "X": 81658997.8051, "Y": 123260312.409, "Z": -9085.18402816}, {"Date": "18 Nov 2013", "Time": "20:31:14.080", "X": 81657187.7025, "Y": 123261045.113, "Z": -9201.18459146}, {"Date": "18 Nov 2013", "Time": "20:32:04.771", "X": 81655675.123, "Y": 123262087.534, "Z": -9342.83736965}, {"Date": "18 Nov 2013", "Time": "20:32:50.316", "X": 81653996.4558, "Y": 123262902.446, "Z": -9406.781534}, {"Date": "18 Nov 2013", "Time": "20:33:40.462", "X": 81652401.8992, "Y": 123263608.22, "Z": -9447.6413373}, {"Date": "18 Nov 2013", "Time": "20:34:31.081", "X": 81650843.8531, "Y": 123264263.055, "Z": -9463.3436887}, {"Date": "18 Nov 2013", "Time": "20:35:19.189", "X": 81649355.8528, "Y": 123264948.013, "Z": -9477.69075914}, {"Date": "18 Nov 2013", "Time": "20:36:10.060", "X": 81647896.4312, "Y": 123265625.276, "Z": -9502.4589425}, {"Date": "18 Nov 2013", "Time": "20:36:58.517", "X": 81646304.1226, "Y": 123266297.884, "Z": -9543.1278776}, {"Date": "18 Nov 2013", "Time": "20:37:40.079", "X": 81644744.1095, "Y": 123266953.943, "Z": -9610.30169048}, {"Date": "18 Nov 2013", "Time": "20:38:24.101", "X": 81643047.7847, "Y": 123267601.327, "Z": -9662.19836118}, {"Date": "18 Nov 2013", "Time": "20:39:07.874", "X": 81641326.9436, "Y": 123268254.877, "Z": -9702.1555487}, {"Date": "18 Nov 2013", "Time": "20:39:46.102", "X": 81639683.7271, "Y": 123268901.356, "Z": -9831.3373117}, {"Date": "18 Nov 2013", "Time": "20:40:21.113", "X": 81637588.8019, "Y": 123269547.799, "Z": -9897.8182517}, {"Date": "18 Nov 2013", "Time": "20:40:59.941", "X": 81644194.8512, "Y": 123270191.981, "Z": -9954.6868628}, {"Date": "18 Nov 2013", "Time": "20:41:39.636", "X": 81642090.361, "Y": 123270837.788, "Z": -10000.2380471}, {"Date": "18 Nov 2013", "Time": "20:42:12.510", "X": 81639883.0765, "Y": 123271484.052, "Z": -10035.205811}, {"Date": "18 Nov 2013", "Time": "20:42:48.104", "X": 81637588.8019, "Y": 123272136.329, "Z": -10059.3287534}, {"Date": "18 Nov 2013", "Time": "20:43:26.757", "X": 81635379.5046, "Y": 123272791.147, "Z": -10073.7137848}, {"Date": "18 Nov 2013", "Time": "20:44:03.384", "X": 81632993.0243, "Y": 123273437.114, "Z": -10074.002824}, {"Date": "18 Nov 2013", "Time": "20:44:35.284", "X": 81630600.6537, "Y": 123274058.474, "Z": -10063.994918}, {"Date": "18 Nov 2013", "Time": "20:45:06.044", "X": 81628278.8531, "Y": 123274678.298, "Z": -10041.769364}, {"Date": "18 Nov 2013", "Time": "20:45:41.918", "X": 81625949.6204, "Y": 123275283.777, "Z": -10006.684076}
```

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.



**satellite.js v1.2.0**  
<https://github.com/shashwatak/satellite-js>

**three.js**  
<http://threejs.org/>

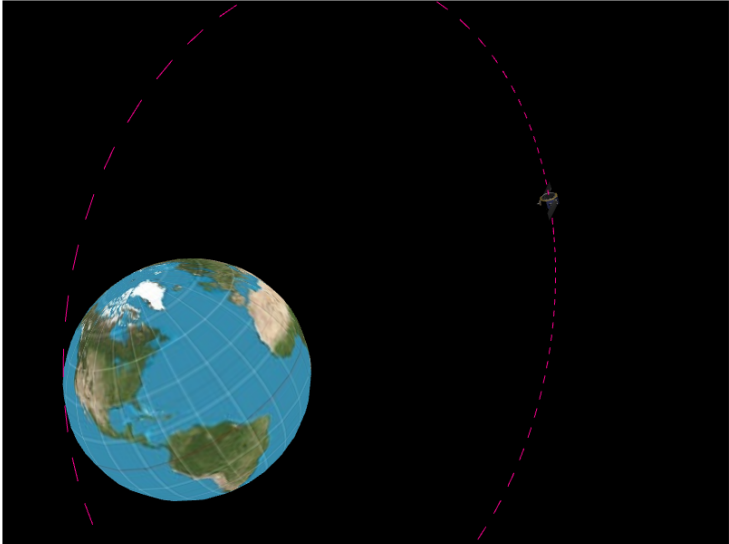


# Tutorials and Demonstrations for X3Dom

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

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.	<a href="#">Part 1</a>	<input type="button" value="Demo 1"/>
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.	<a href="#">Part 2</a>	<input type="button" value="Demo 2"/>
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.	<a href="#">Part 3</a> <a href="#">Input Data</a>	<input type="button" value="Demo 3"/>
Before starting Demo 4, copy and paste the Output Data into a text editor, save the file with a *.json extension and upload it with the Browse button on Demo 4.	<a href="#">Output Data</a>	<input type="button" value="Demo 4"/>
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.	<a href="#">A Vision for a WMVS</a>	

### Prototype Web Visualization of a GMAT Generated Trajectory



Date: 25 Jul 2014 Time: 11:29:10.811

Molniya.json

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

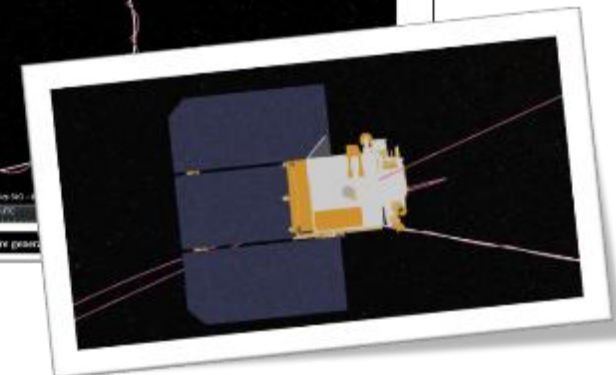
- A Three Part tutorial that explains how to create a web-based mission visualization from trajectory data exported from the General Mission Analysis Tool (GMAT)
- Links lead to the tutorials, buttons activate the demonstrations
- Includes a link to a vision document for a Web-based Space Mission Visualization 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	2014-07-22 T 11:29:11 Z",	-137380000, 21487600, 75679900,
22 Jul 2014 16:50:29.706	-139	2014-07-22 T 11:30:11 Z",	-137394000, 21492800, 75653100,
22 Jul 2014 19:58:17.654	-137	2014-07-22 T 11:33:21 Z",	-137438000, 21509000, 75567800,
22 Jul 2014 22:49:39.159	-134	2014-07-22 T 11:43:21 Z",	-137573000, 21559700, 75297600,
23 Jul 2014 01:10:15.710	-130	2014-07-22 T 12:13:08 Z",	-137945000, 21705900, 74476800,
23 Jul 2014 03:15:24.444	-126	2014-07-22 T 13:39:55 Z",	-138776000, 22092100, 71948900,
23 Jul 2014 05:06:47.357	-121	2014-07-22 T 16:50:30 Z",	-139253000, 22724900, 65710500,
23 Jul 2014 06:46:08.345	-115	2014-07-22 T 19:58:18 Z",	-137836000, 23040700, 58673800,
23 Jul 2014 08:14:52.984	-110	2014-07-22 T 22:49:39 Z",	-134793000, 23037000, 51508000,
23 Jul 2014 09:34:12.984	-104	2014-07-23 T 01:10:16 Z",	-130940000, 22802600, 45108000,
23 Jul 2014 10:45:09.816	-989	2014-07-23 T 03:15:24 Z",	-126382000, 22397700, 39022600,
23 Jul 2014 11:48:37.120	-932	2014-07-23 T 05:06:4	
	"	2014-07-23 T 06:46:0	
	"	2014-07-23 T 08:14:5	
	"	2014-07-23 T 09:34:1	
	"	2014-07-23 T 10:45:1	

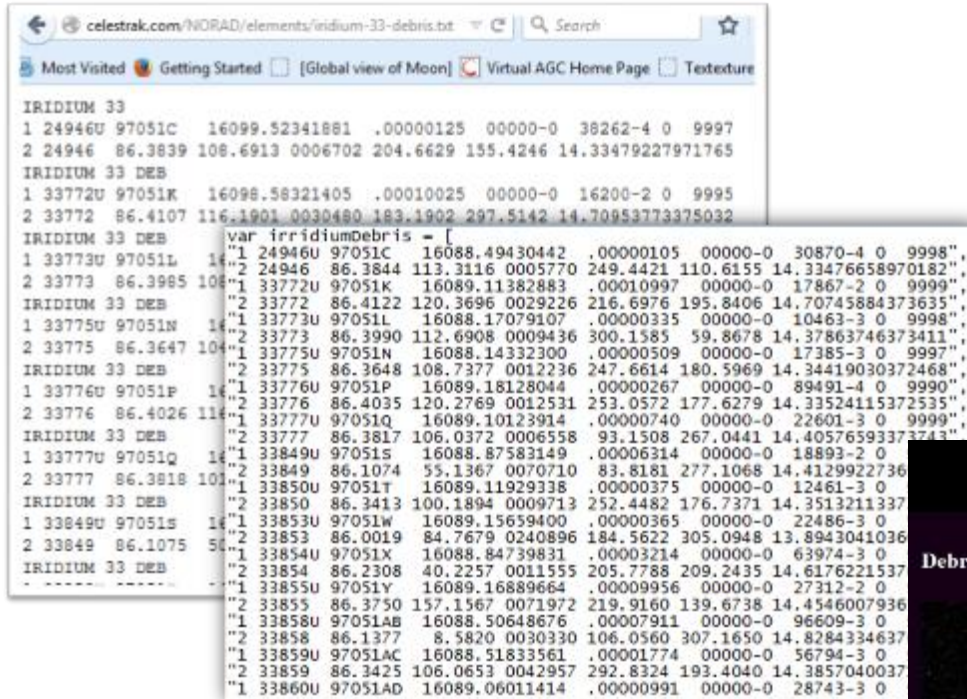
- Trajectory data generated from a GMAT tutorial
- Converted to a JavaScript string variable with Excel

- 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](http://daoneil.github.io/spacemission/Apps/EarthToMoon_Demo.html)

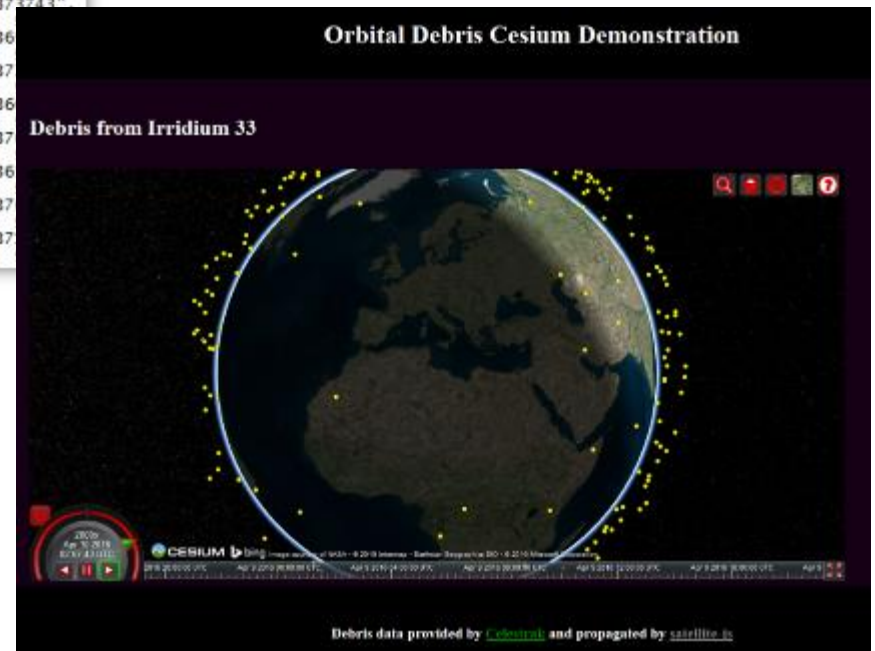
# Orbital Debris Propagation with Satellite-js and Visualized in Cesium



```
celestrak.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 33773 86.3985 108.6913 0006702 204.6629 155.4246 14.33479227971765
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 86.3648 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 .000006314 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 33853U 97051W 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
IRIDIUM 33 DEB
1 33860U 97051AD 16089.06011414 .00000991 00000-0 28743-3 0
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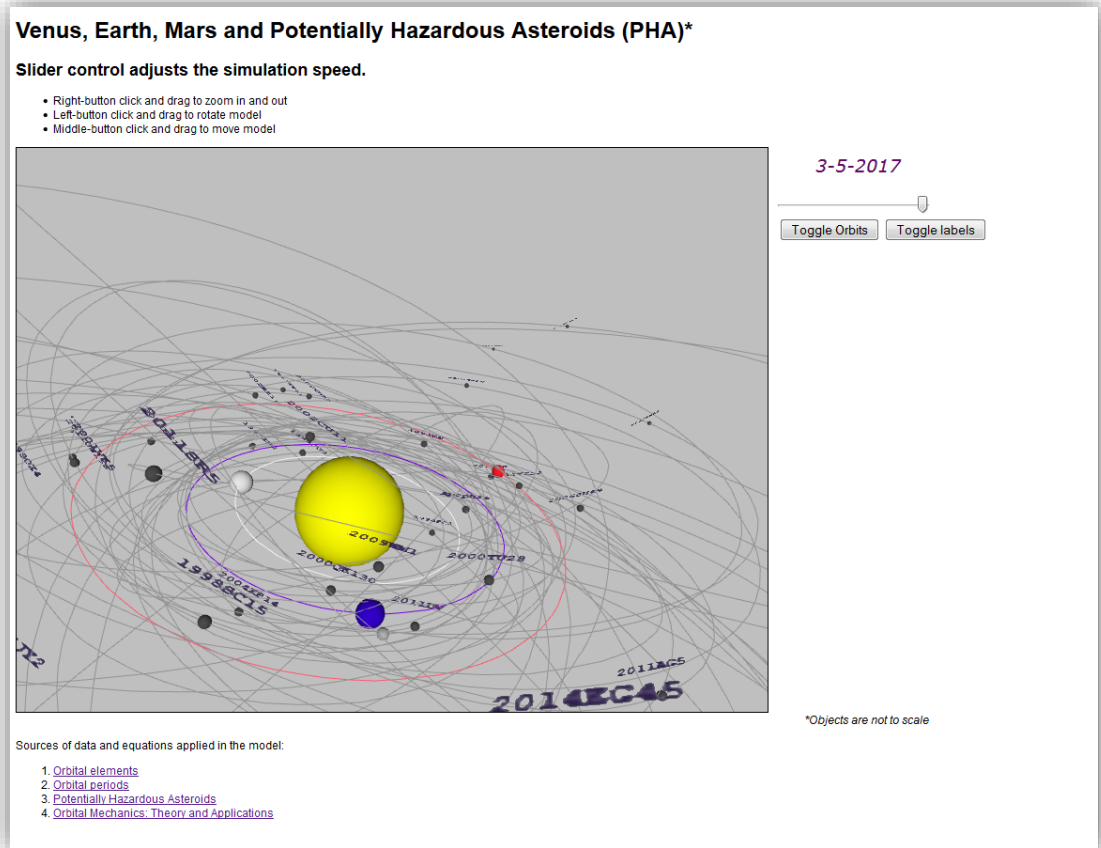
- Two Line Element (TLE) data provided by Celestrak
- Data converted to a JavaScript string variable with Excel
- Positions propagated via Satellite-js

- Two Line Element set  
[https://en.wikipedia.org/wiki/Two-line\\_element\\_set](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](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](mailto:daniel.a.oneil@nasa.gov)