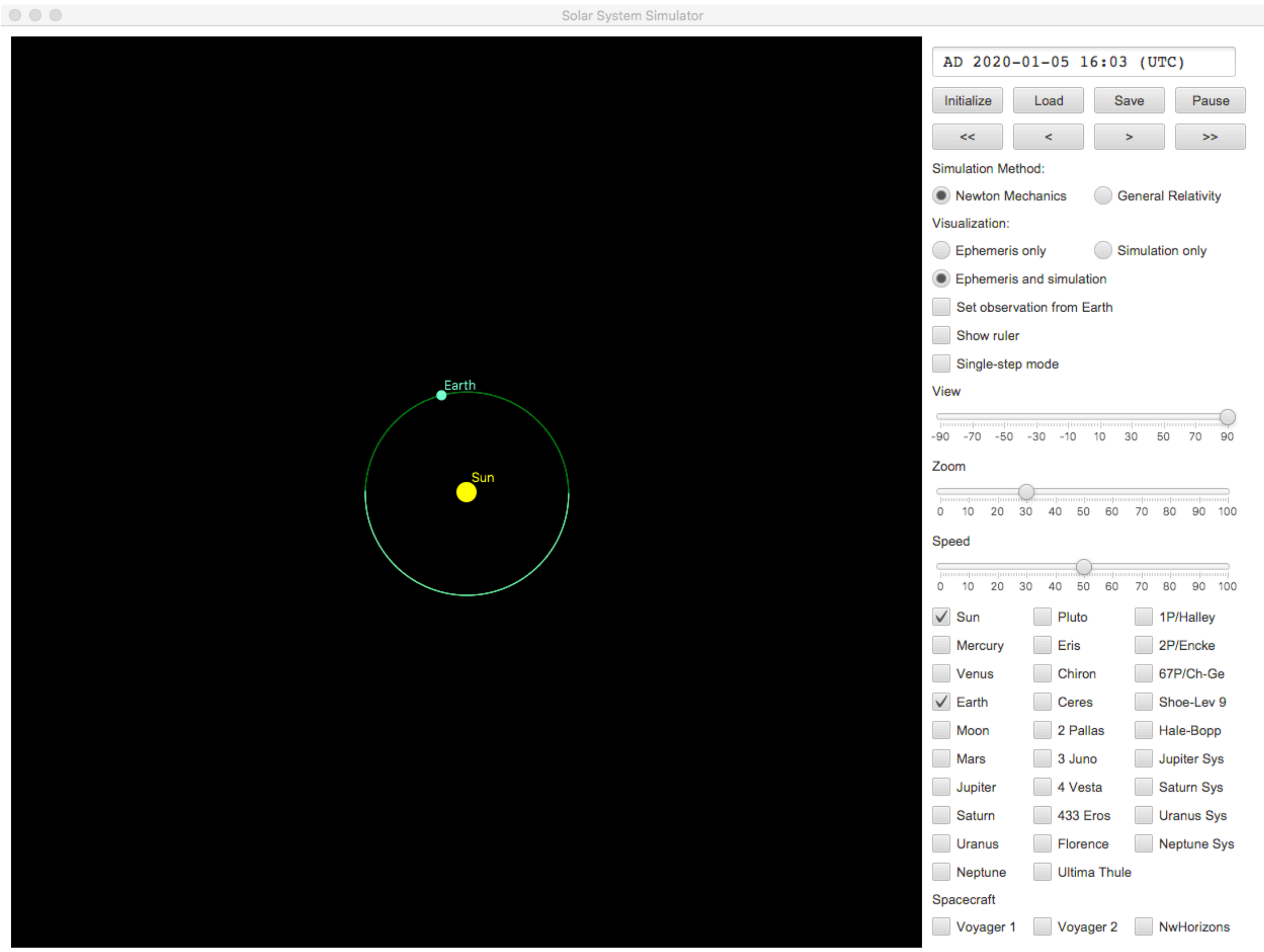
Solar System Simulator - Manual

Author: Nico Kuijpers
Date: January 5, 2020

Introduction

The Solar System Simulator is written in Java. Positions and velocities of 42 solar system bodies and 3 spacecraft are continuously updated using either Newton Mechanics or General Relativity. Initial positions and velocities are obtained from Nasa JPL's ephemerides. While simulating, both simulated positions and ephemeris data can be visualised for comparison. Source code is made publicly availaible under the MIT licence.

Manual



Set date and time

Enter date and time in the text box on the top-right and click Initialize. The state of the Solar System will be initialized to the entered date and time (Coordinated Universal Time).

Load/save simulation state
Click the Load or Save button to load a simulation state from file or save the current simulation state to file.

Pause and advance simulation
To pause a running simulation click the Pause-button. To advance click the > button and to advance fast click >>. The simulation goes backward in time when < or << is clicked. Check ‘Single-step mode’ to advance 1 minute at a time when clicking < or > or slowly advancing with time steps of 1 minute when clicking << or >>.

Simulation Method
Choose between Newton Mechanics and General Relativity to advance the simulation. Although General Relativity is more accurate, usually Newton Mechanics is the best choice as it requires less computational effort to advance a single time step. Normally, a single time step is 1 hour, but when ‘Single step mode’ is checked, the time step is 1 minute.

Visualization
You can choose to show either the ephemerides data (orbits shown in green), simulation results (orbits shown in cyan), or both. Check the Solar System bodies that you want to visualize in the right-bottom area. Check ‘Set observation from Earth’ to view directly at the Sun or another solar system body from the surface of the Earh. This view should be used to observe a Mercury transit, Venus transit, a solar eclipse or the Galilean Moons (four largest moons of Jupiter). Check ‘Show ruler’ to show a ruler at the left-bottom of the viewing area. The ruler indicates either km (normal view) or degrees/arc minutes (Observation from Earth).

When you point your mouse pointer at an object and press the left mouse button, the selected object will move to the center of your present view. It is also possible to drag the view by pressing the left mouse button and moving the mouse while keeping the left mouse button pressed. In the ‘Observation from Earth’ view mode, the time shown will shift according to the distance between the selected object and the Earth. For instance, when the Sun is selected, the time increases with 8 minutes, which corresponds to the time needed for light to travel from the Sun to the Earth.

View slider
In Normal view mode, the Solar System bodies are viewed from ‘above’ when the View slider is set at 90 degrees and from the ‘front’ when the View slider is set at 0 degrees. In the ‘Observation from Earth’ view mode, the slider can be used to indicate the latitude of the viewing position on the surface of the Earth. Note that in reality the Earth’s axis is tilted, which causes the seasons. This is not taken into account in the simulator and, therefore, the value at which the slider is set is not exactly the same as the lattitude of a viewing position.

Zoom slider
Use this slider to zoom into the center of the viewing area. All Solar System bodies are represented by colored disks with a minimum size. However, if you zoom in, the disk size may increase, especially for larger bodies such as the Sun and Jupiter. In the 'Observation from Earth' view mode the size of the disk corresponds to the apparent view as seen from the surface of the Earth (measured in arc minutes).

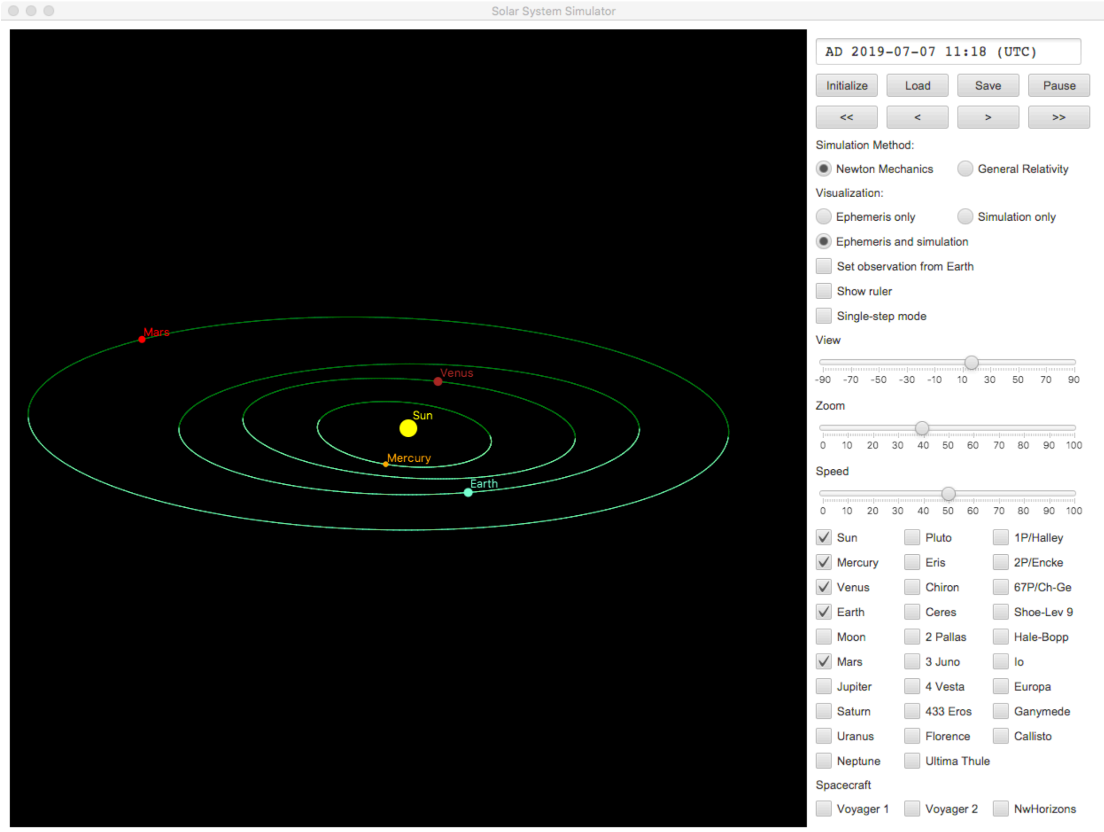
Speed slider
Use this slider to set the speed with which the simulation advances after clicking the < or > button. When 'Single-step mode' is checked, this slider can be used to control the speed of the simulation after clicking << or >>.

Examples
On the next pages you will find some screenshots of the Solar System Simulator. When comparing these screenshots to other drawings and images of the same events, please note that the ecliptic plane in the Earth-to-Sun view is horizontal, whereas in real images it is somewhat tilted.

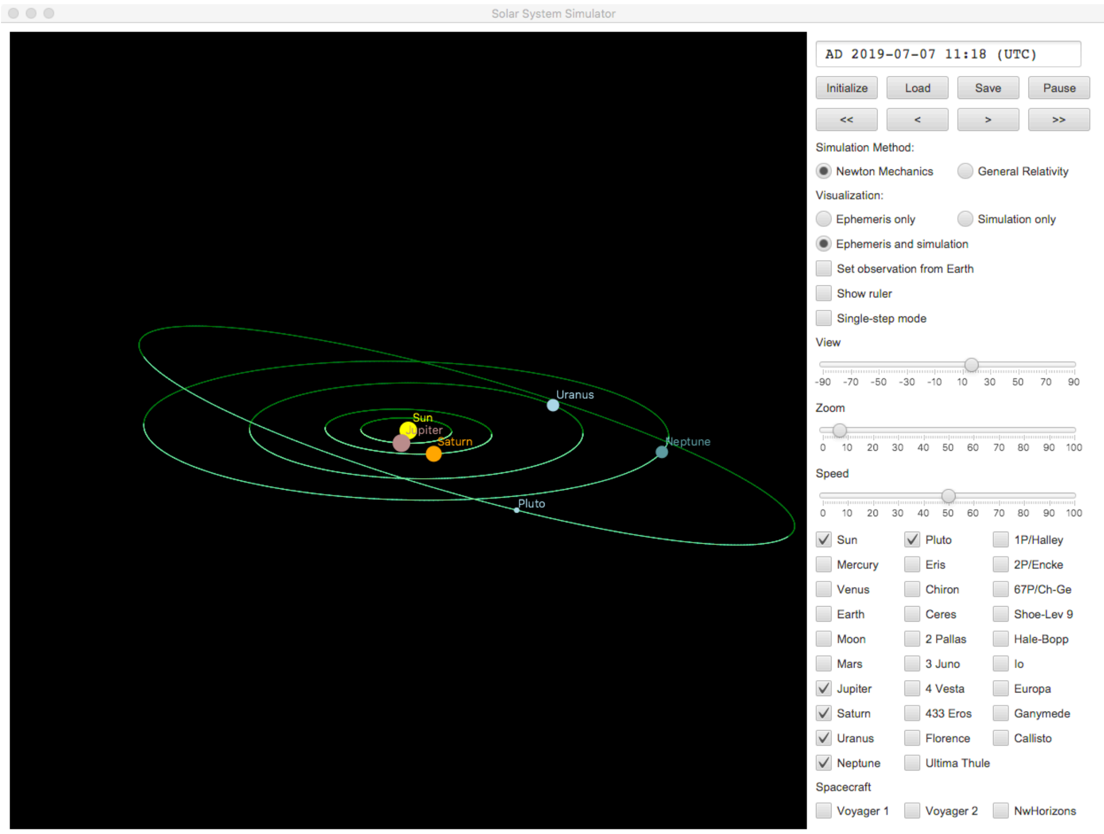
On the final pages of this manual you will learn how to adjust the orbits of planets, moons, and spacecraft.

Have fun!

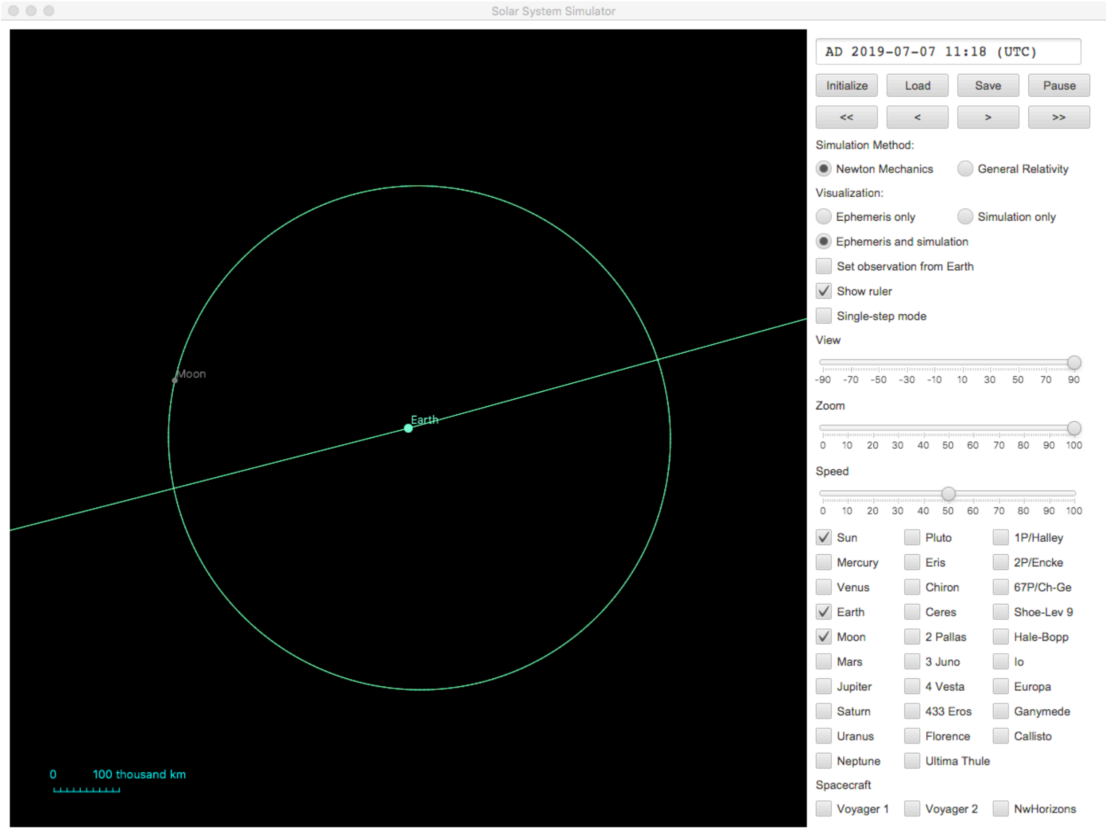
The inner planets of the Solar System (July 7, 2019)



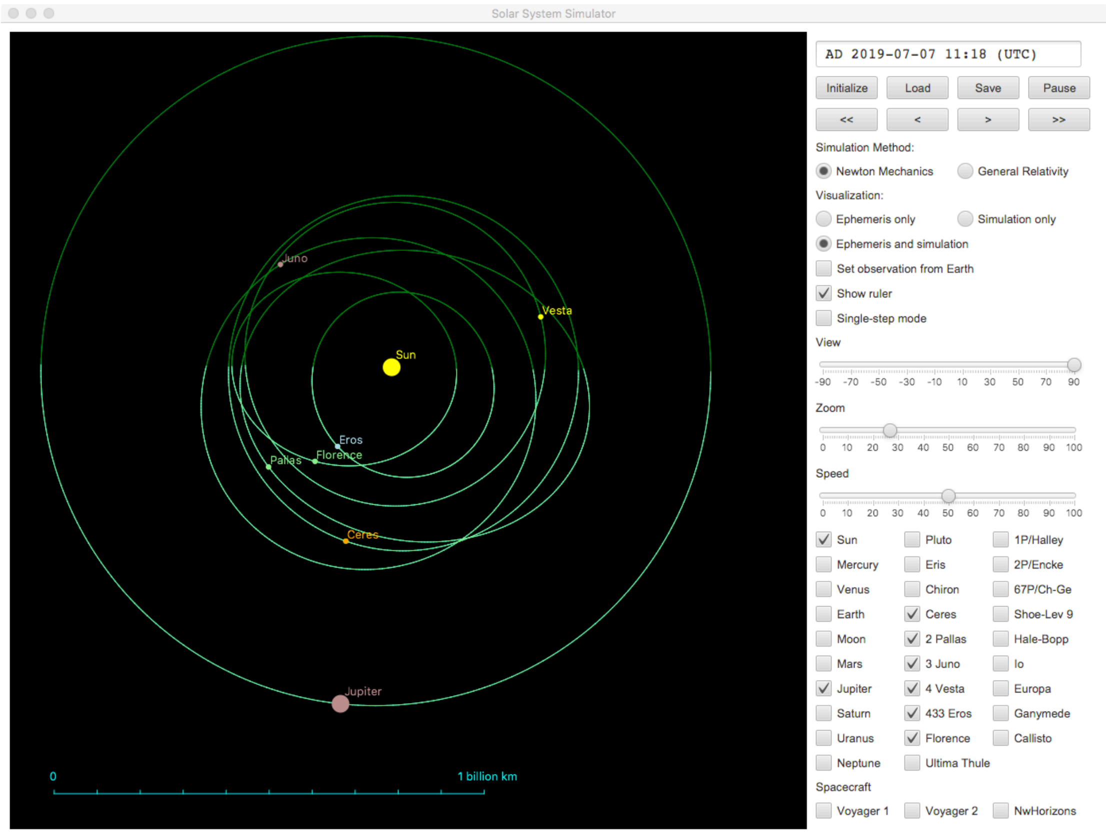
The outer planets of the Solar System (July 7, 2019):



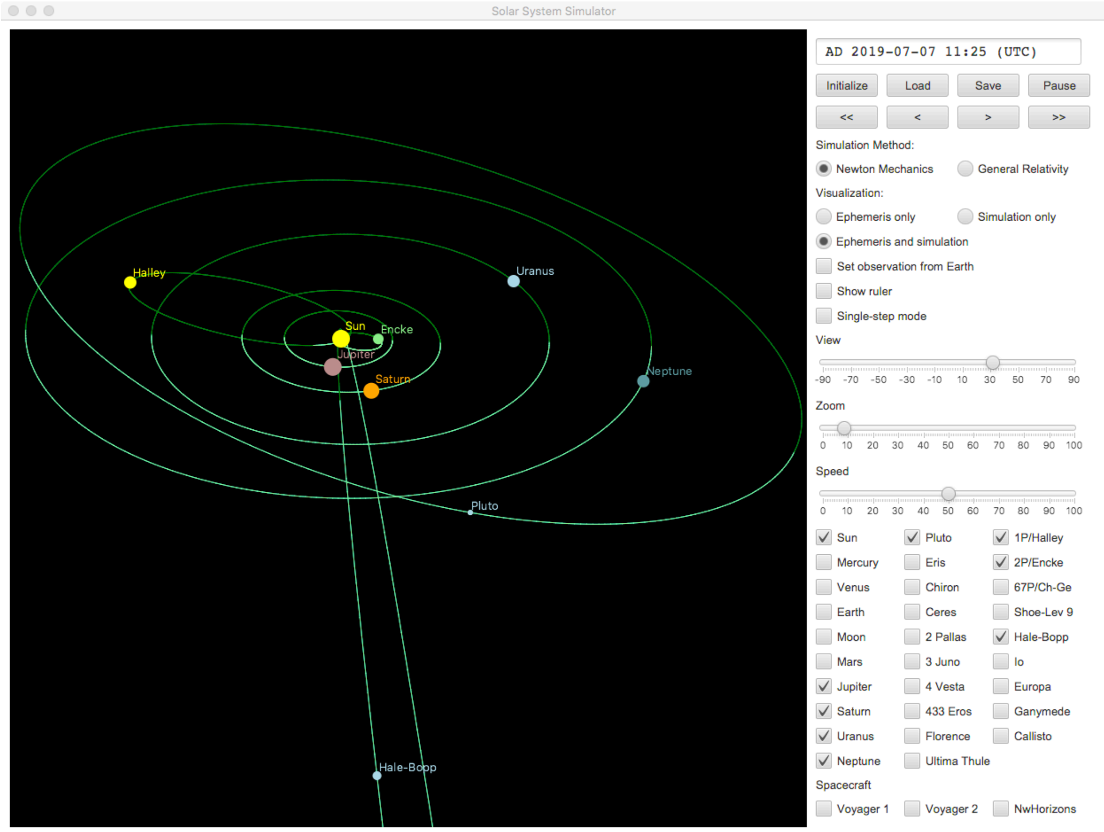
The Earth-Moon system as viewed from above (July 7, 2019):



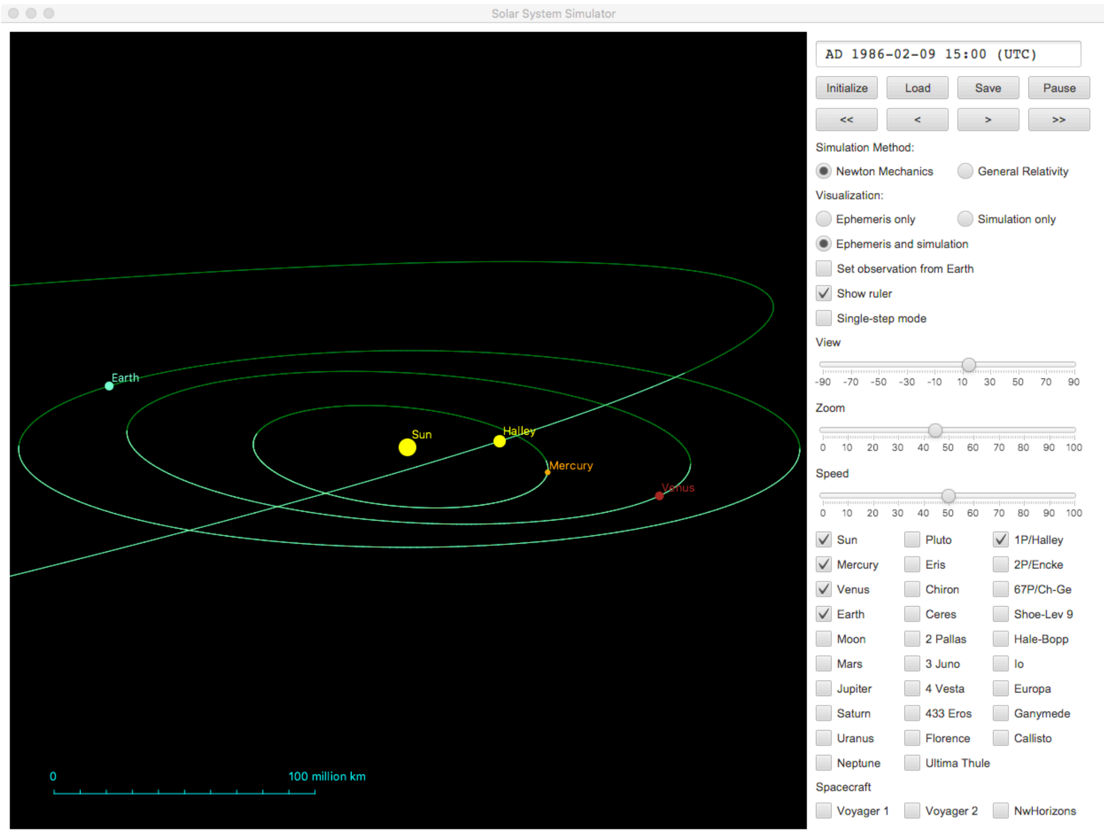
Jupiter and the asteroids as viewed from above (July 7, 2019):



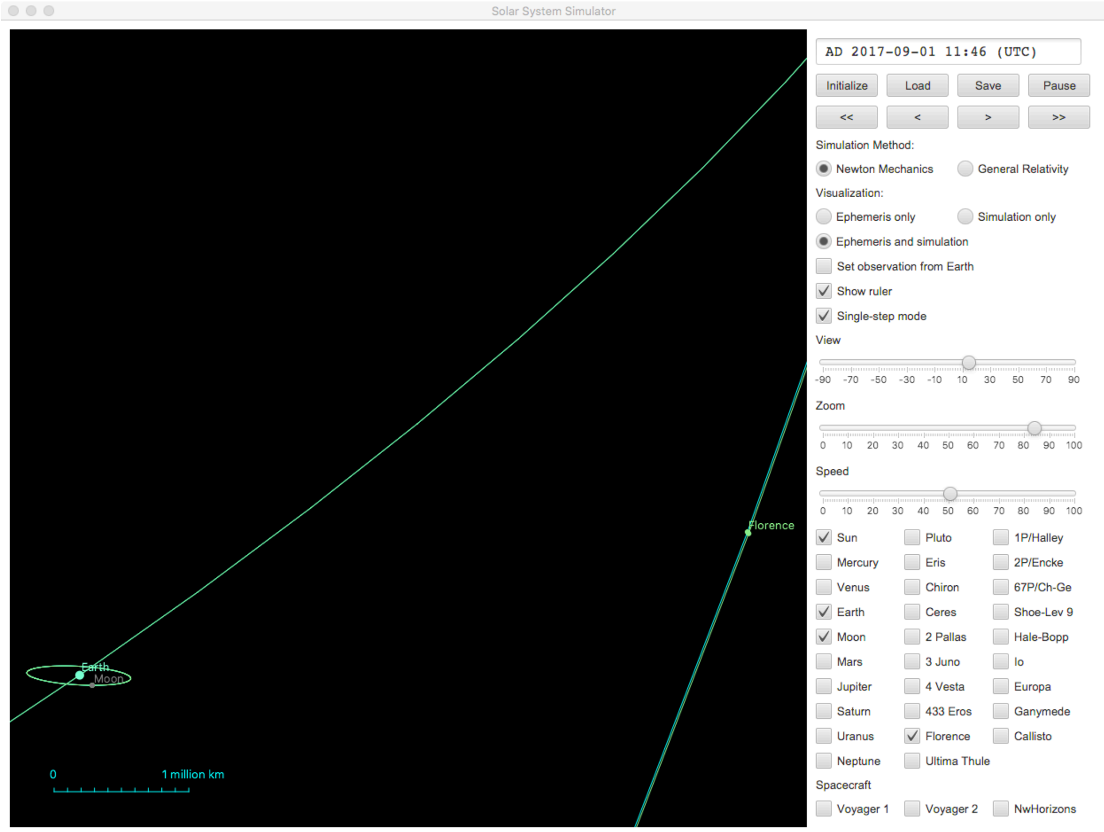
The outer planets and comets (July 7, 2019):



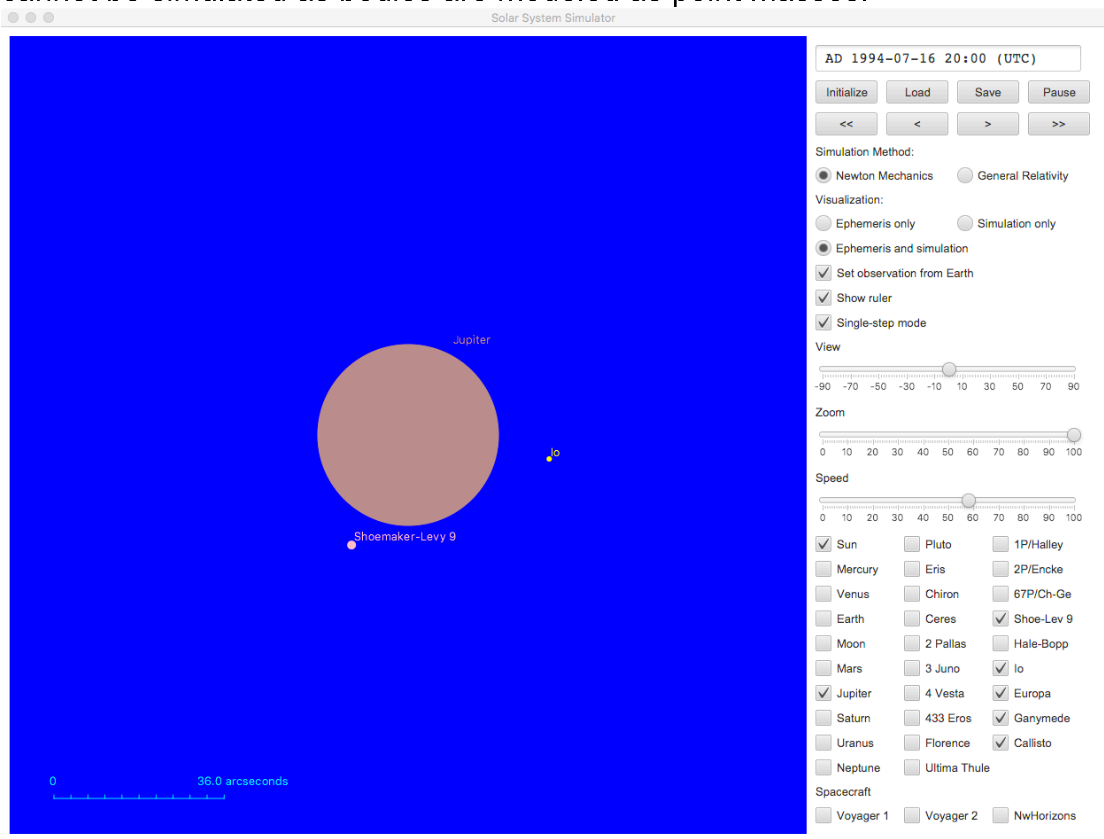
Halley's Comet at its perihelion (February 9, 1986):



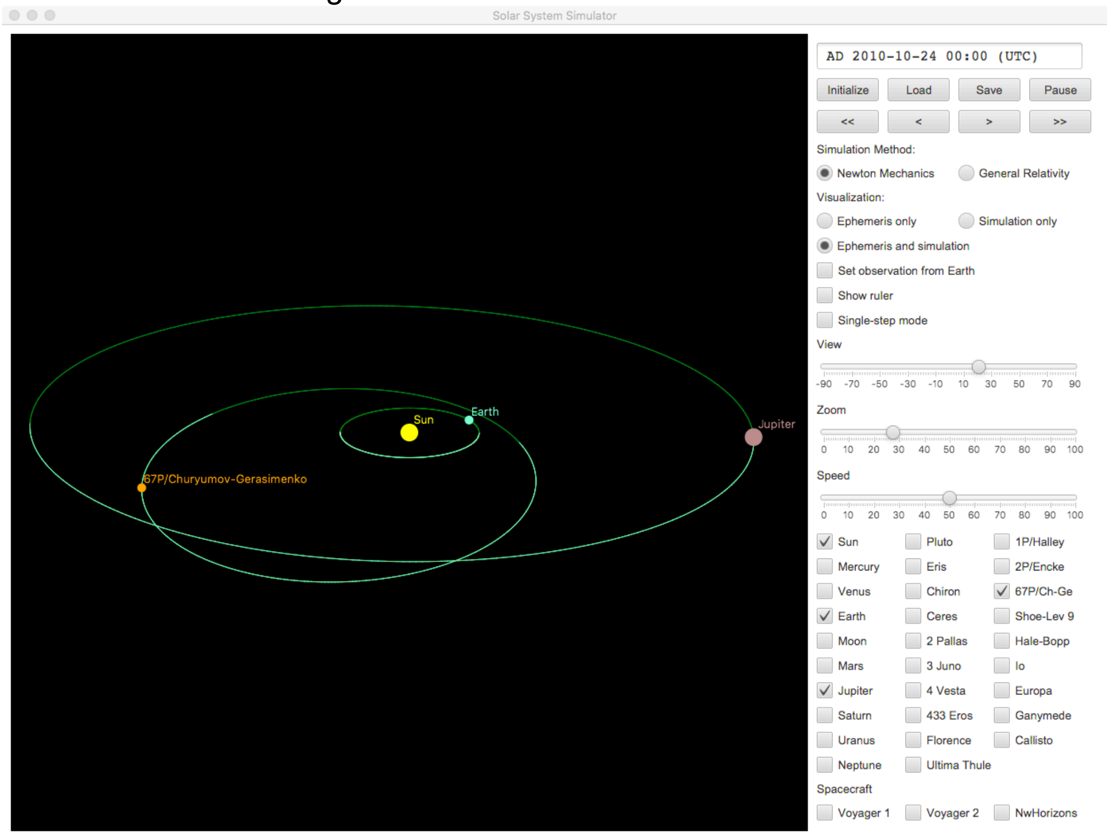
Earth, Moon and near-Earth asteroid Florence (September 1, 2017):



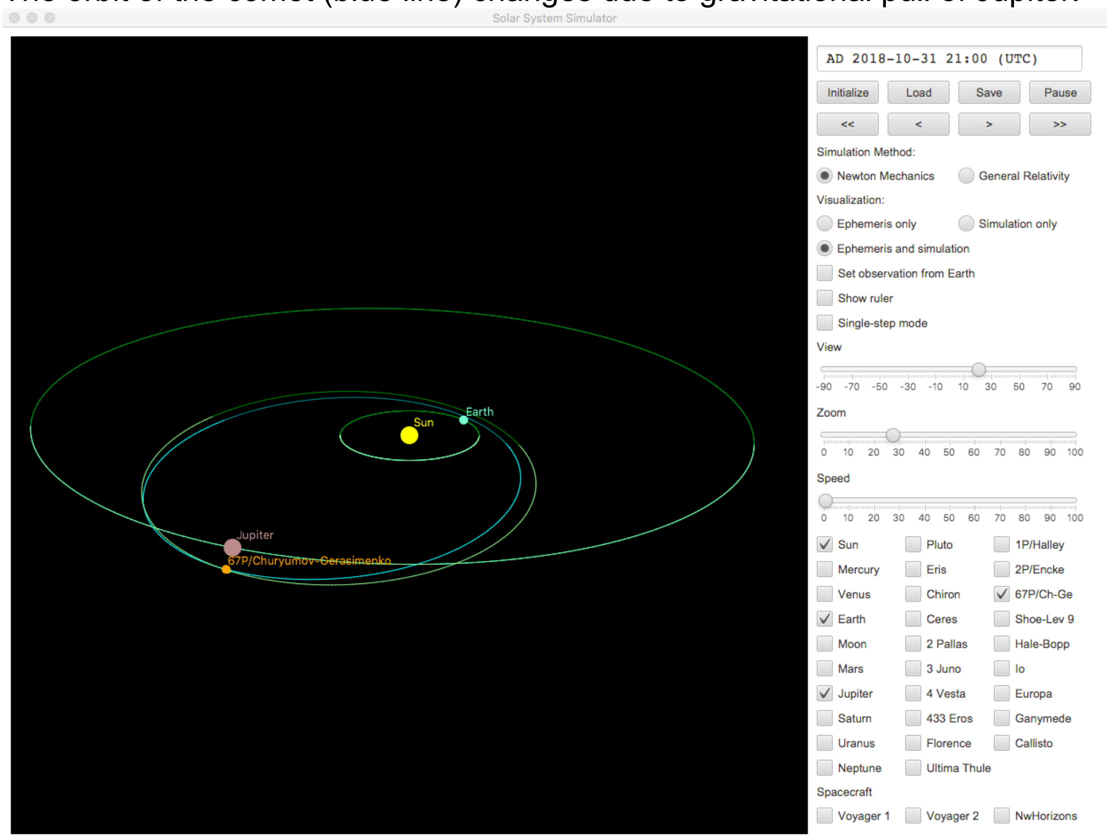
Jupiter, Io and Shoemaker-Levy 9 as observed from the Earth (July 16, 1994). Simulation was started at May 8, 1994. Impact took place somewhat later, but cannot be simulated as bodies are modeled as point masses.



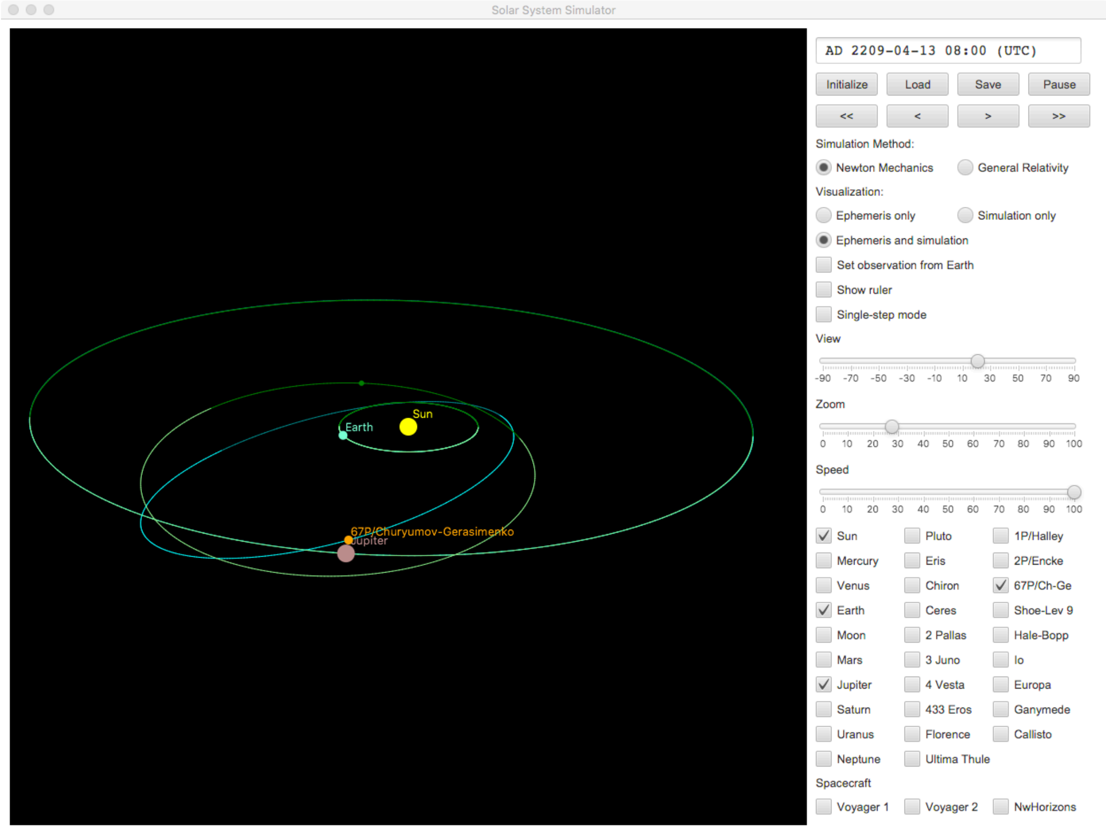
Jupiter and 67P/Churyumov-Gerasimenko (October 24, 2010).
Start of simulation using Newton Mechanics.



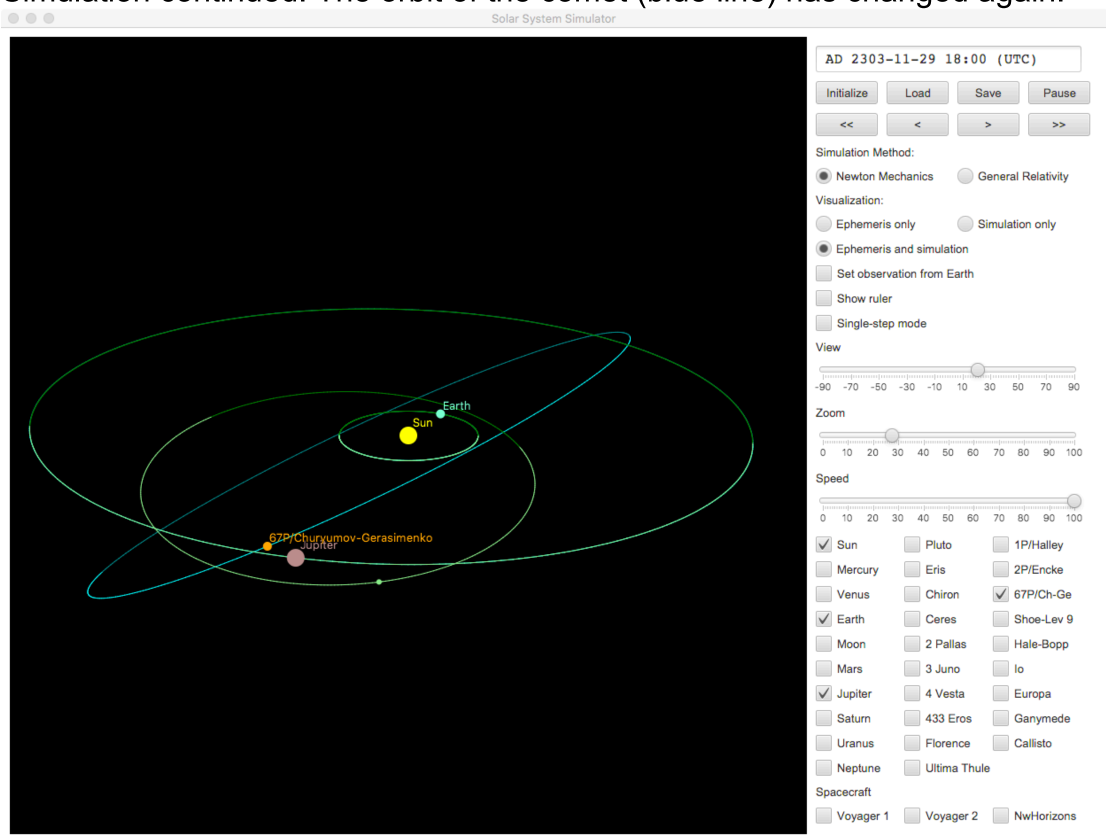
Jupiter and 67P/Churyumov-Gerasimenko (October 31, 2018)
The orbit of the comet (blue line) changes due to gravitational pull of Jupiter.



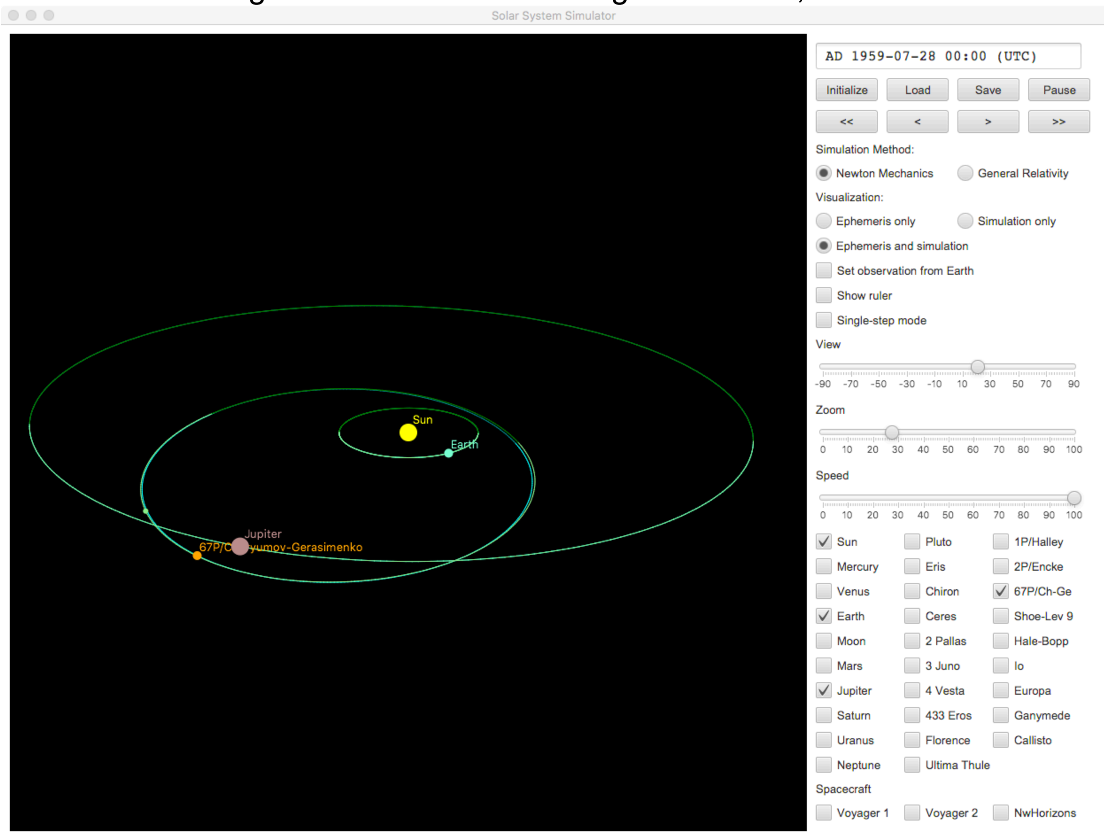
Jupiter and 67P/Churyumov-Gerasimenko (April 13, 2209)
Simulation continued. The orbit of the comet (blue line) has changed again.



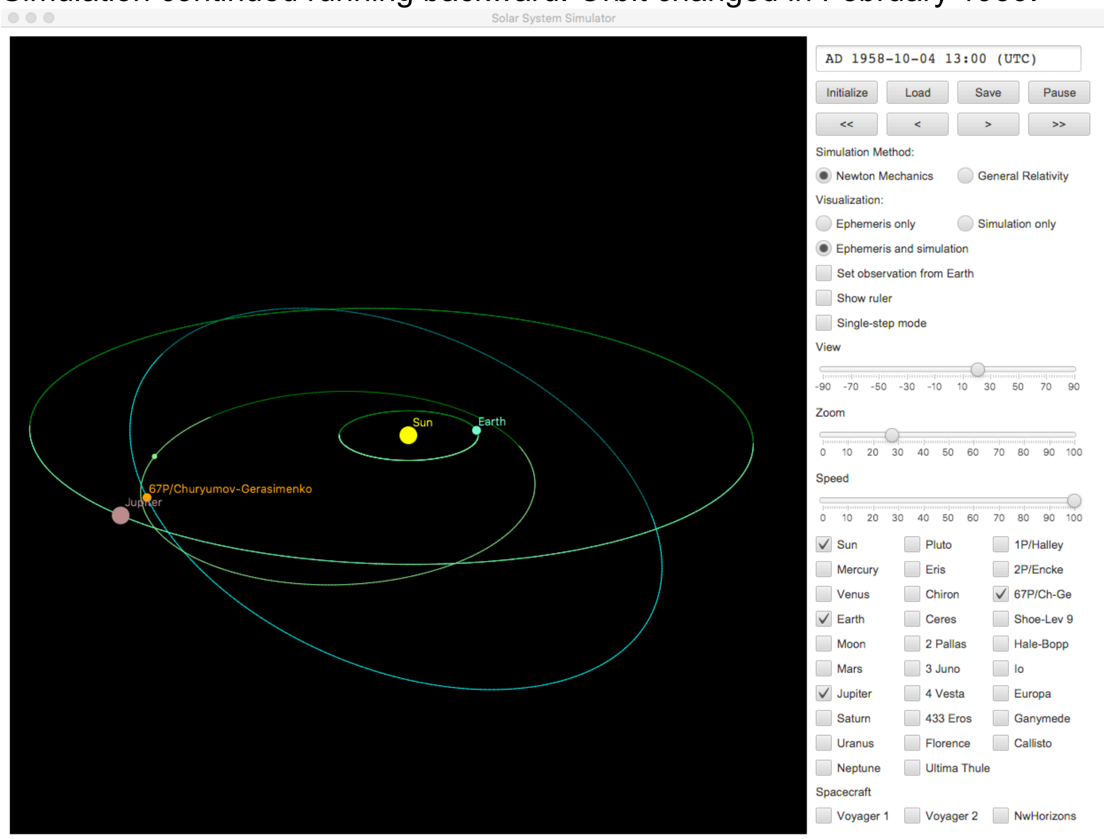
Jupiter and 67P/Churyumov-Gerasimenko (November 29, 2303)
Simulation continued. The orbit of the comet (blue line) has changed again.



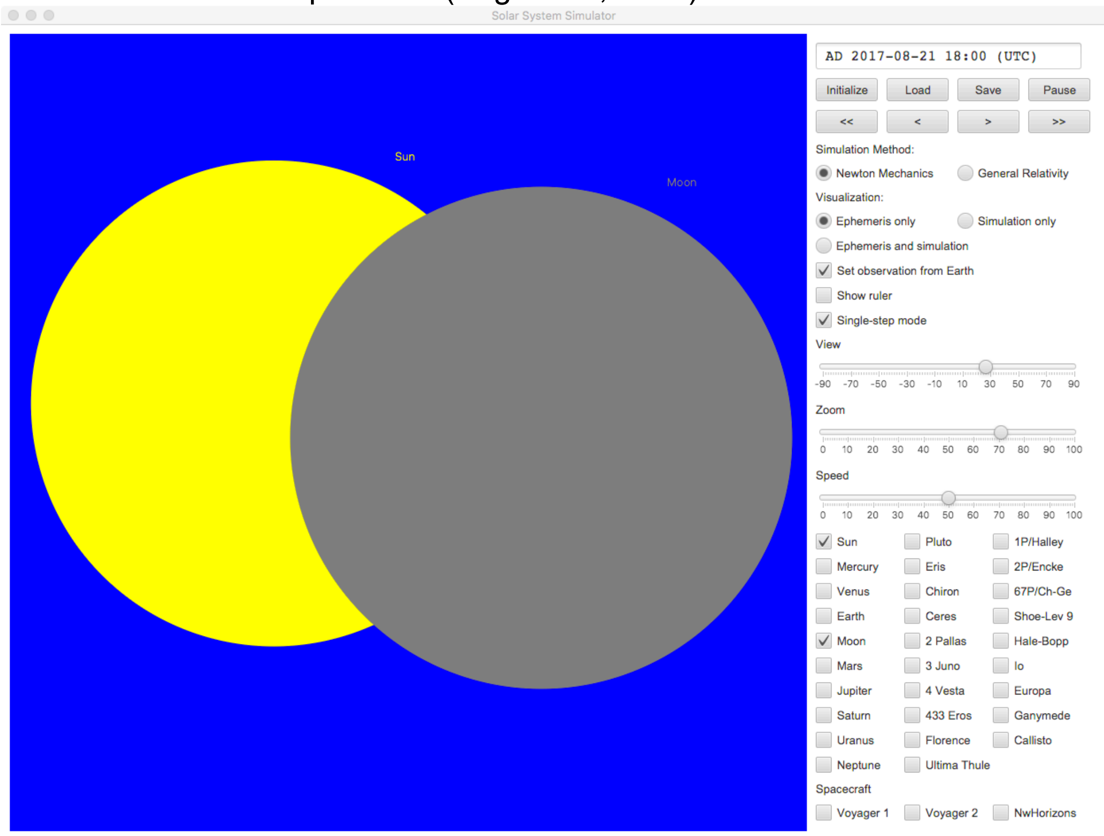
Jupiter and 67P/Churyumov-Gerasimenko (July 28, 1959)
Simulation running backward in time starting October 24, 2010



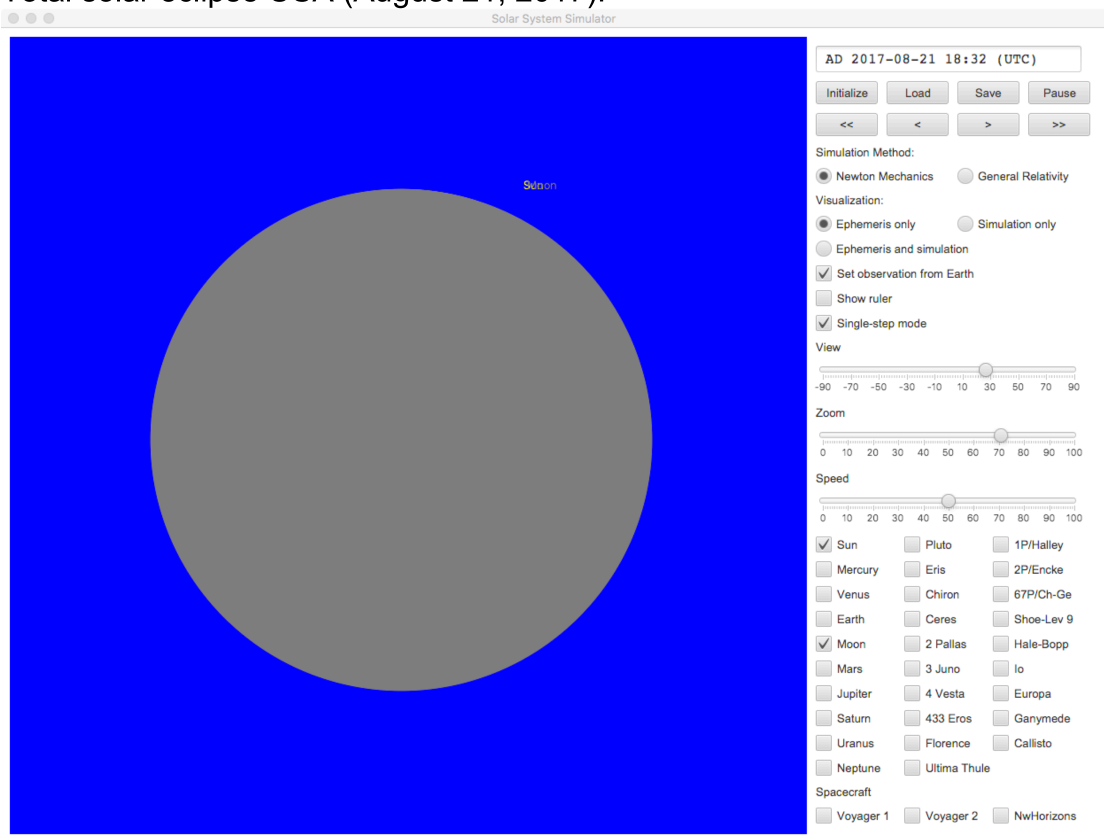
Jupiter and 67P/Churyumov-Gerasimenko (October 4, 1958)
Simulation continued running backward. Orbit changed in February 1959.



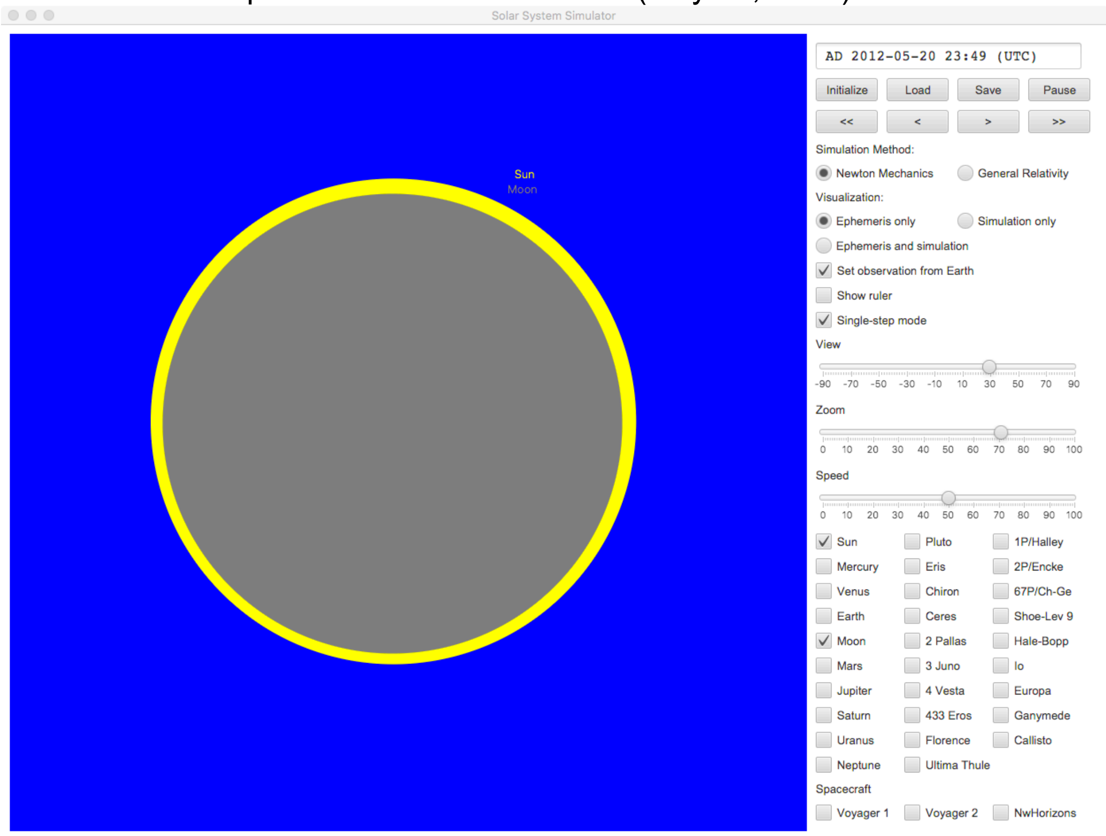
Start of total solar eclipse USA (August 21, 2017):



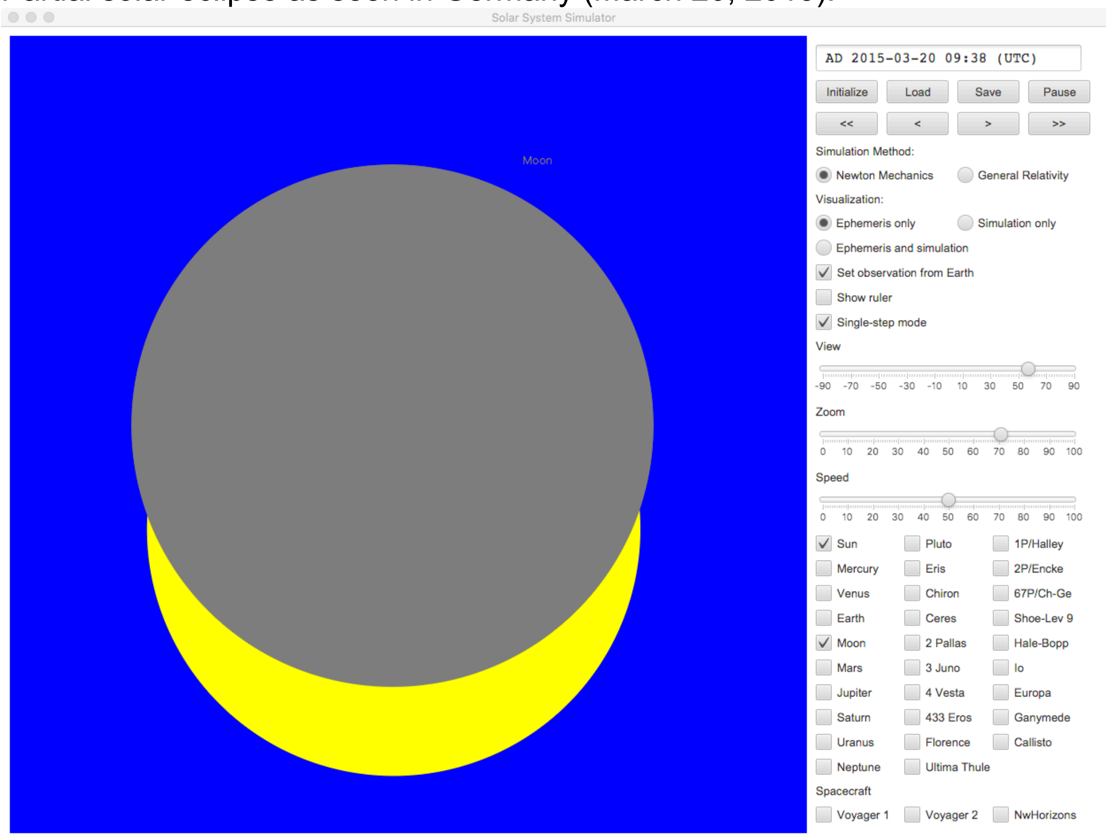
Total solar eclipse USA (August 21, 2017):



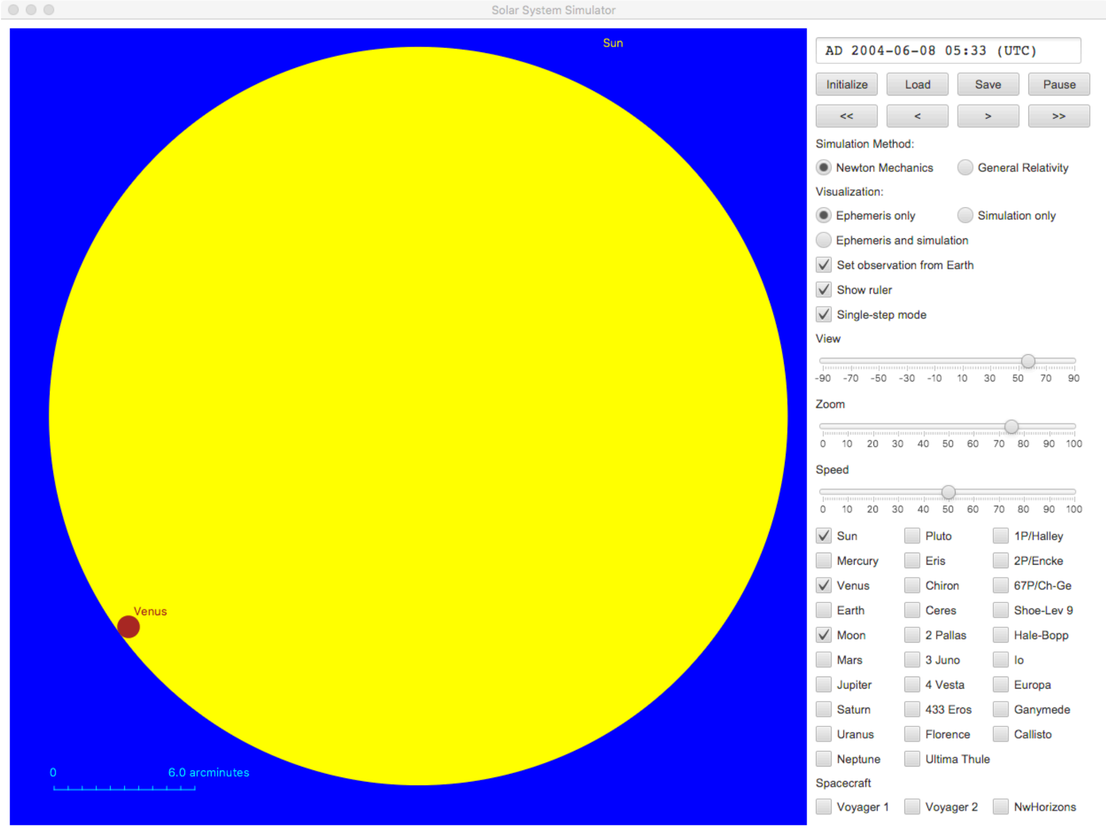
Annular solar eclipse as seen in Novosibirsk (May 20, 2012):



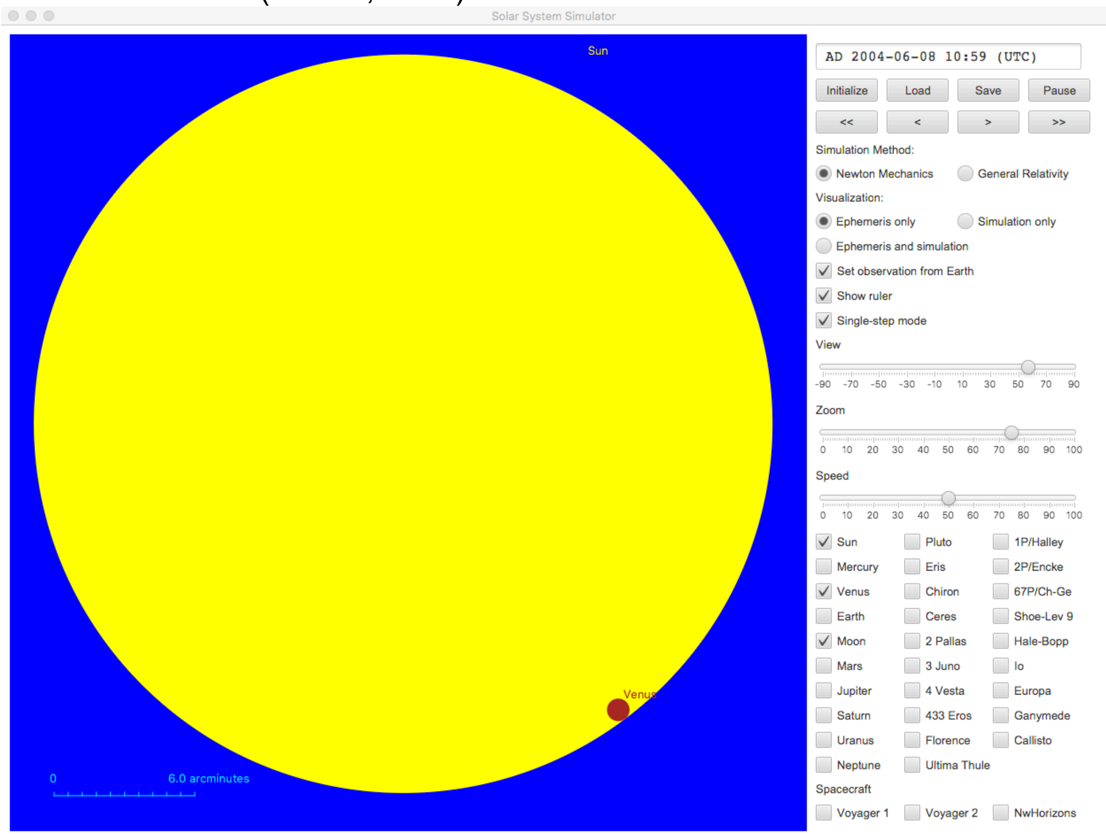
Partial solar eclipse as seen in Germany (March 20, 2015):



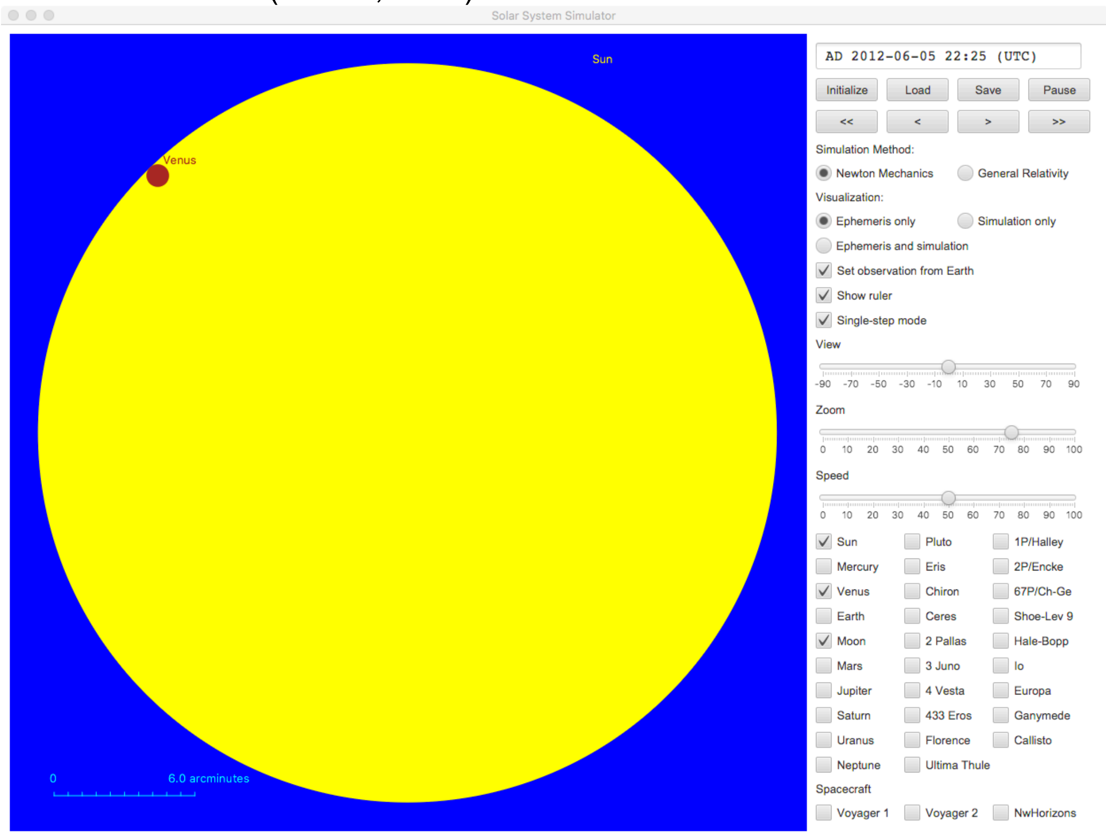
Venus transit start (June 8, 2004):



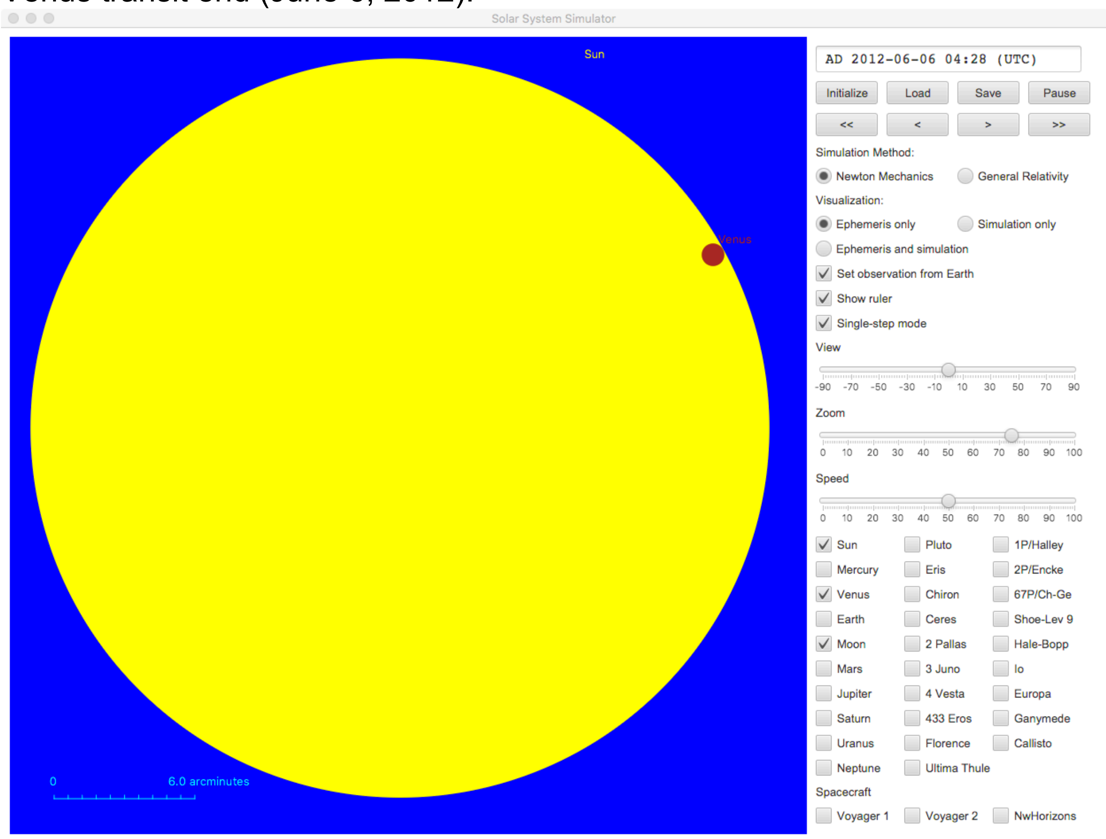
Venus transit end (June 8, 2004):



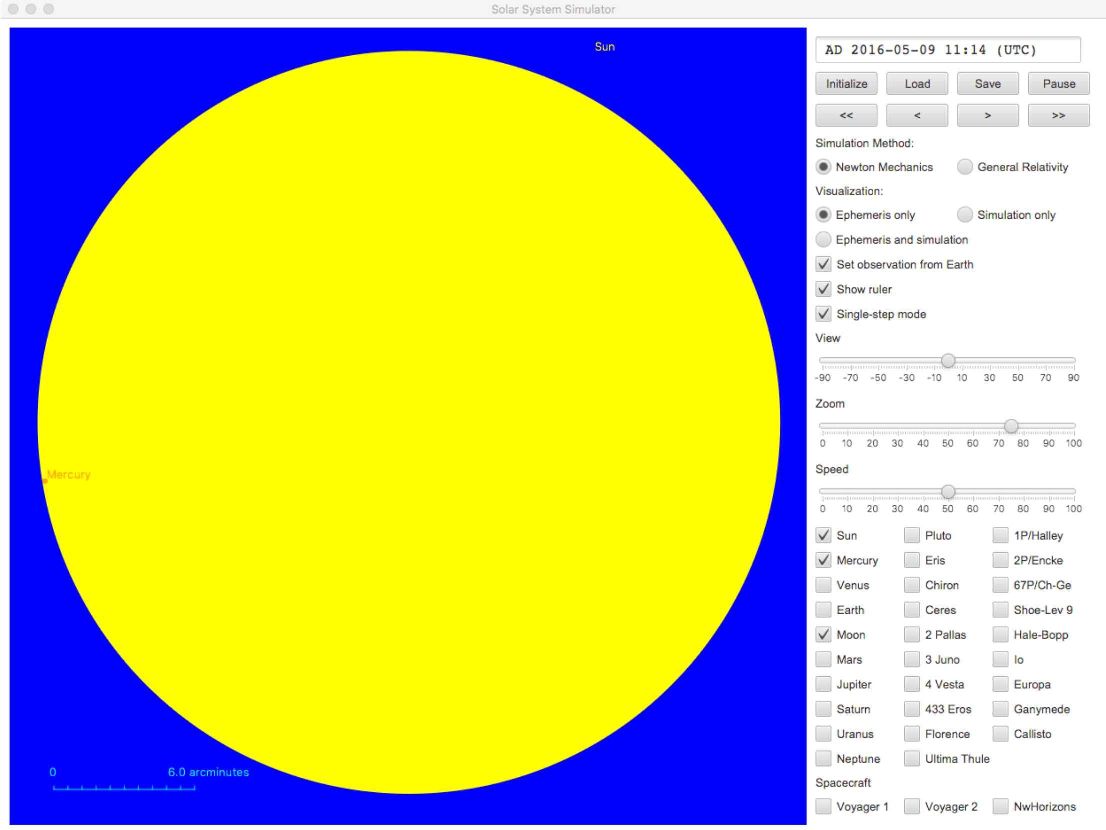
Venus transit start (June 5, 2012):



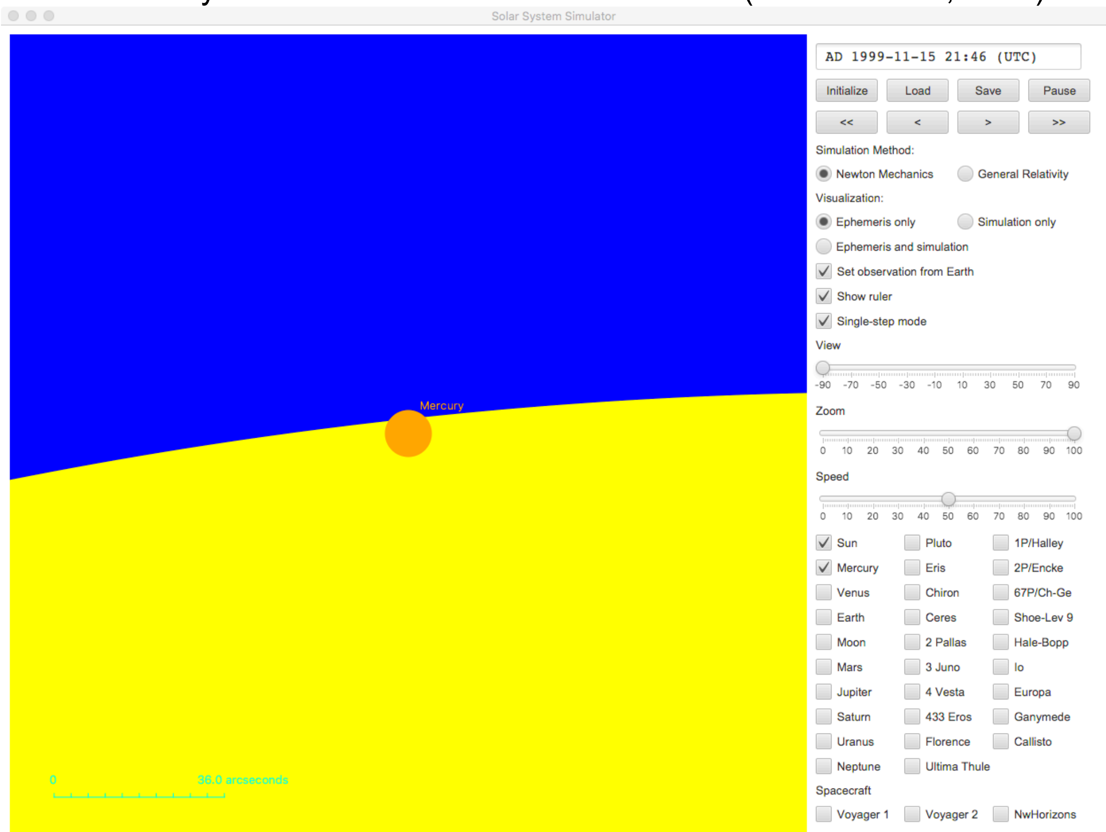
Venus transit end (June 6, 2012):



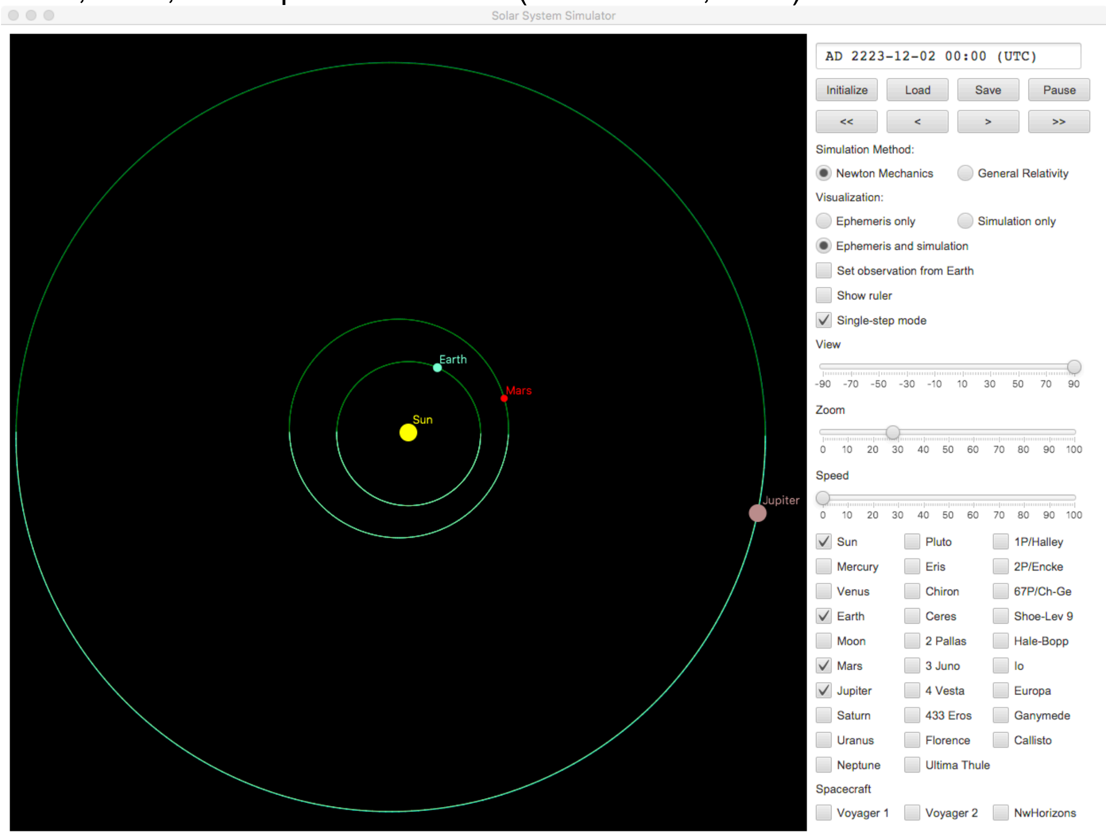
Mercury transit start (May 9, 2016)
Look for the small orange disk at the left.



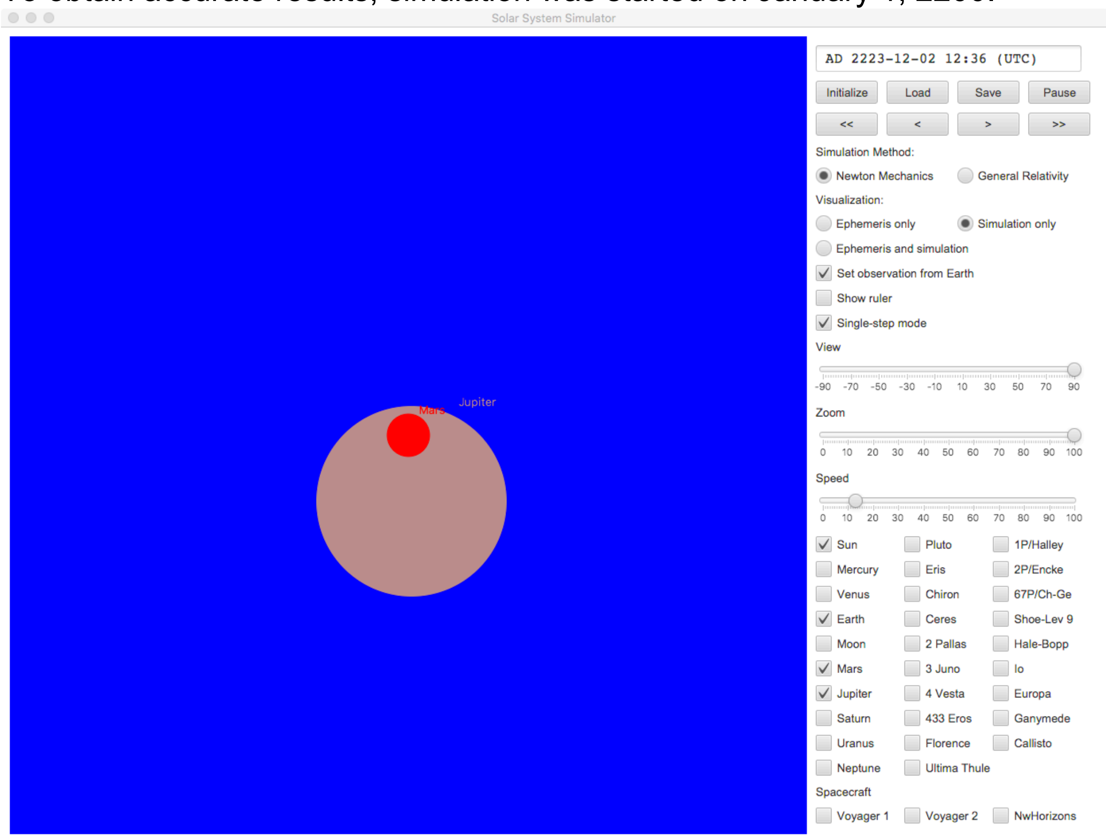
Partial Mercury transit as viewed from New Zealand (November 15, 1999)



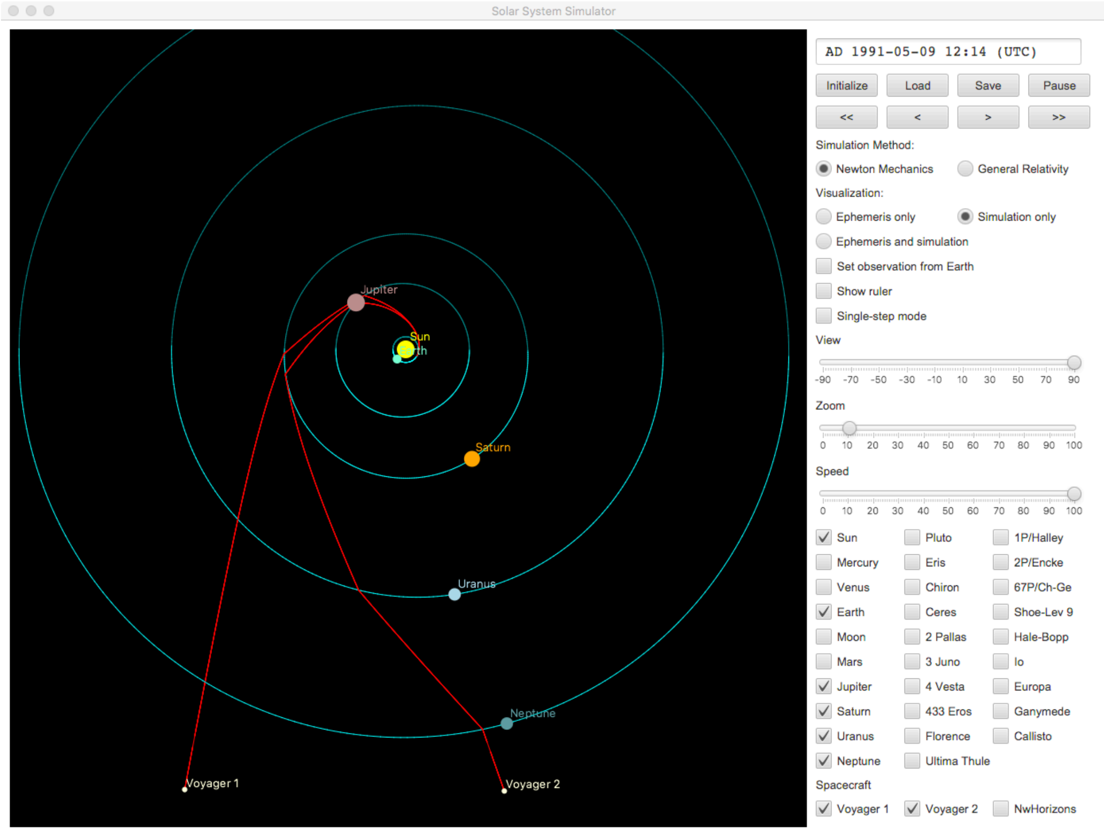
Earth, Mars, and Jupiter on one line (December 2, 2223)



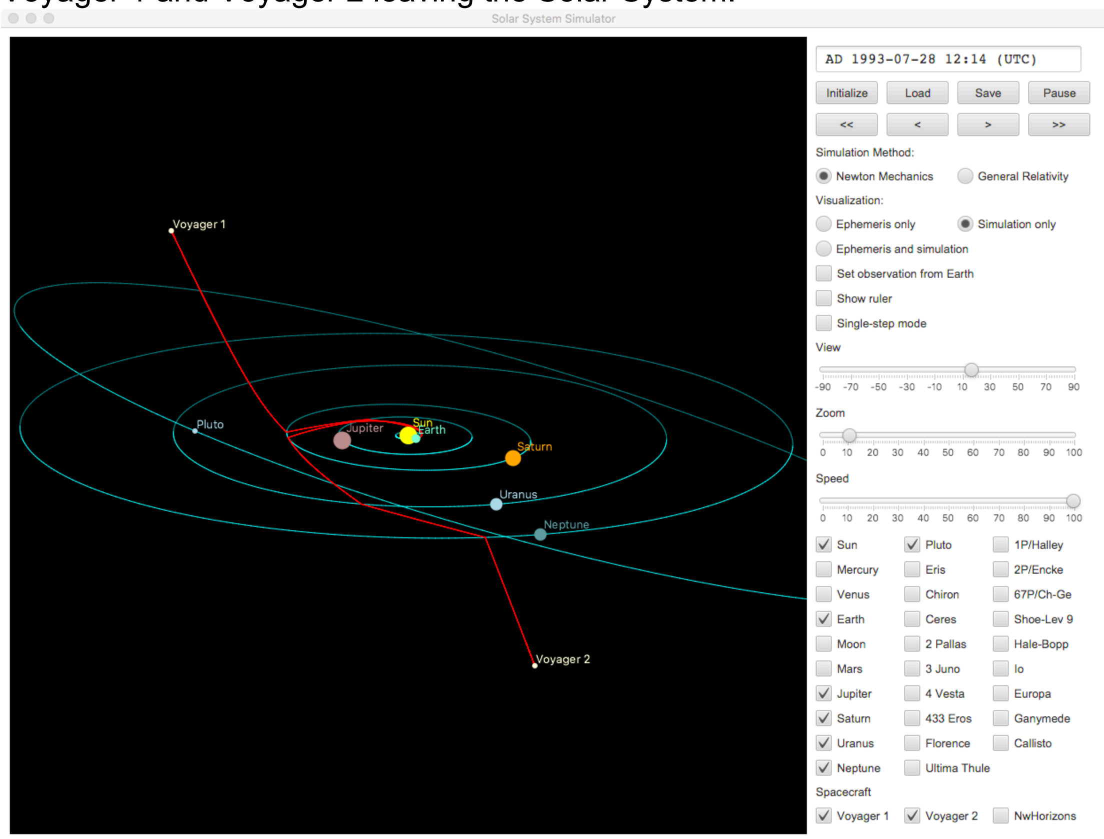
Observing Mars en Jupiter from the Earth (December 2, 2223)
Accurate ephemeris is valid from January 1, 1620 through January 31, 2200.
To obtain accurate results, simulation was started on January 1, 2200.



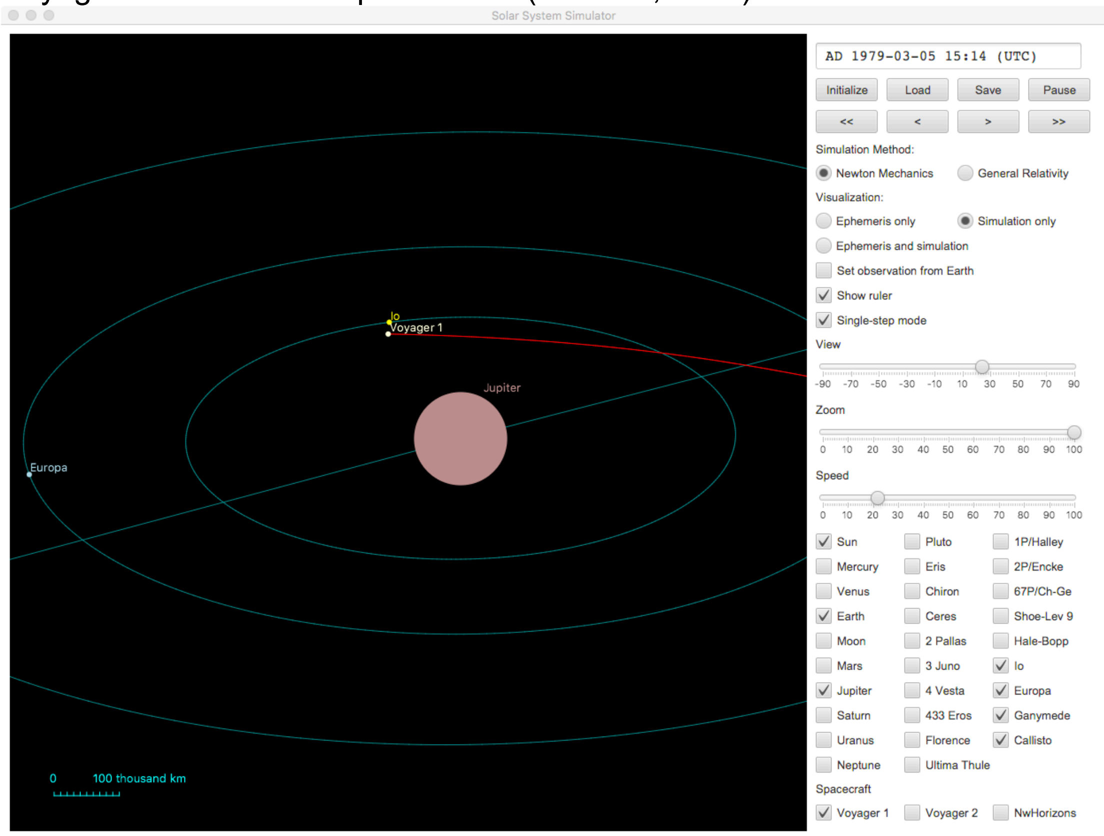
Trajectory of Voyager 1 and Voyager 2. Simulation was started on August 15, 1977 before launch and finished in 1991.



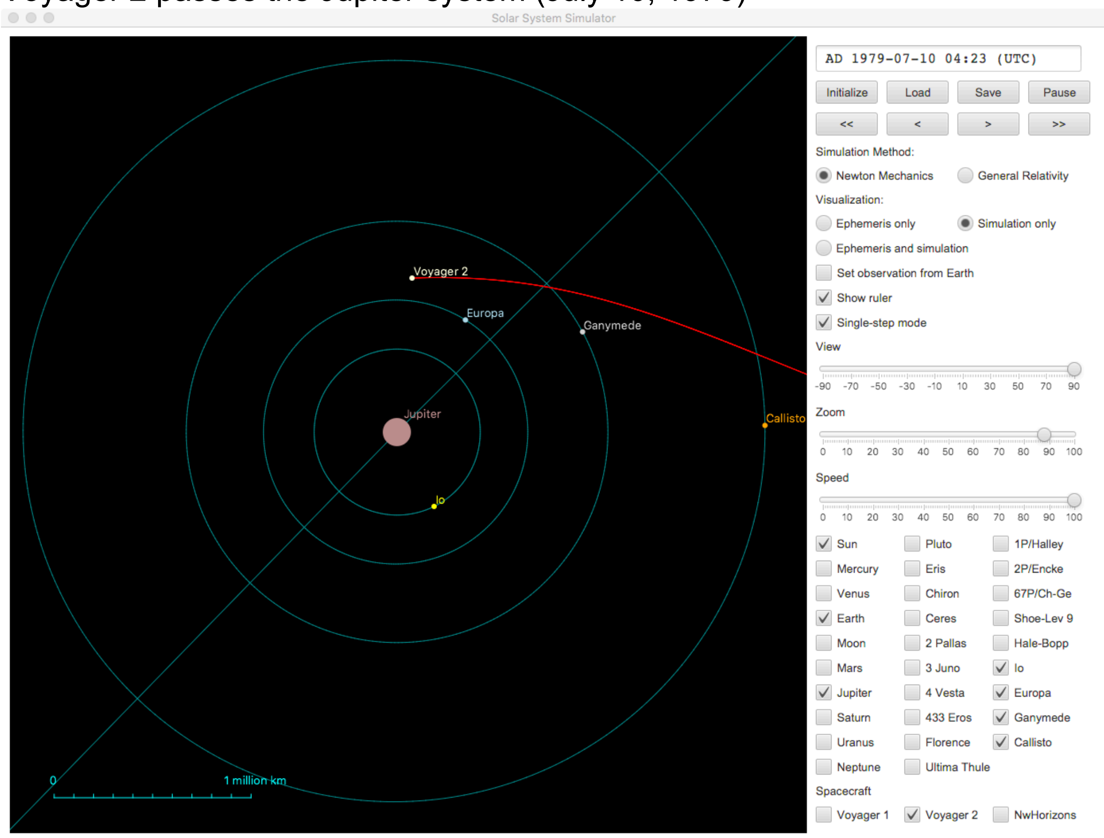
Voyager 1 and Voyager 2 leaving the Solar System.



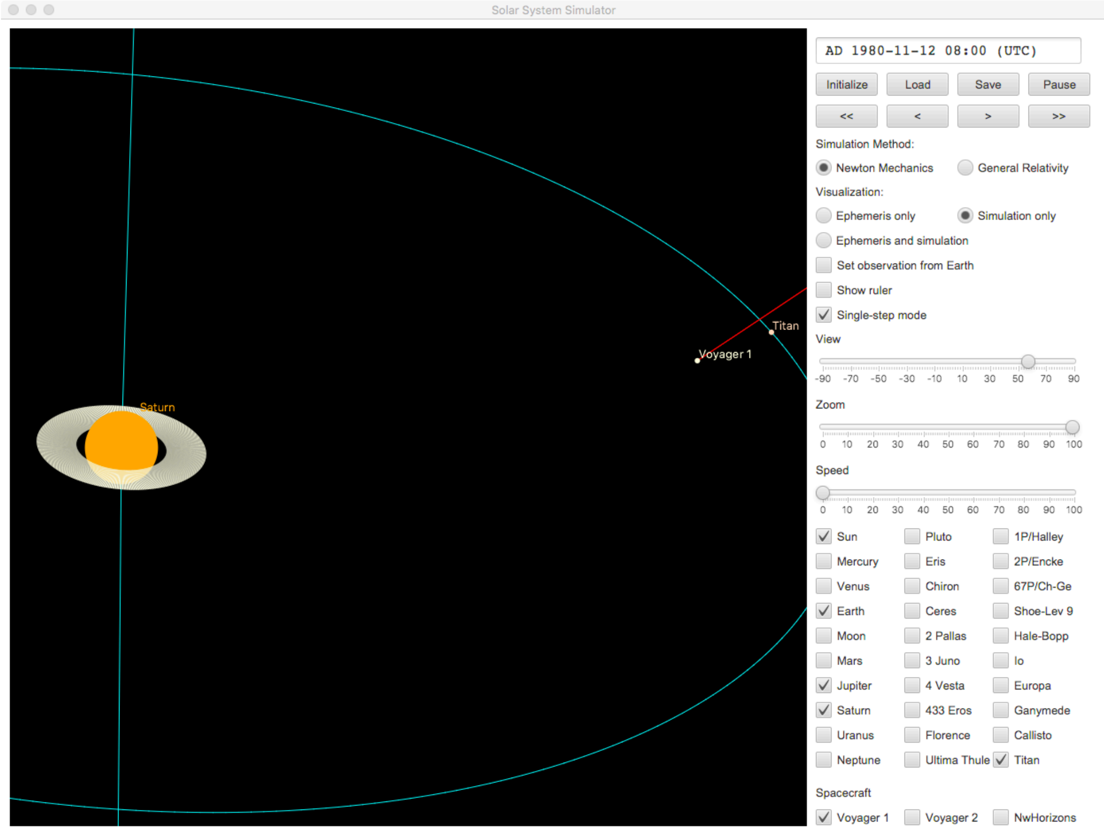
Voyager 1 encounters Jupiter and Io (March 5, 1979)



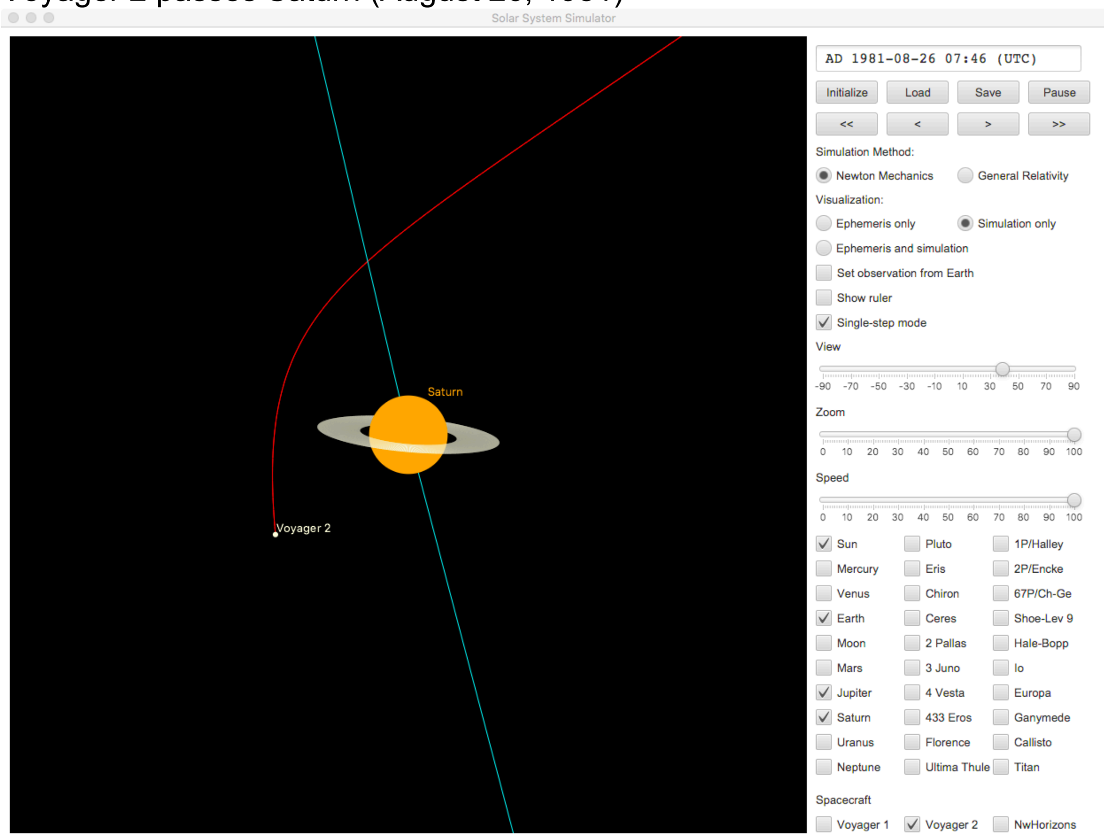
Voyager 2 passes the Jupiter system (July 10, 1979)



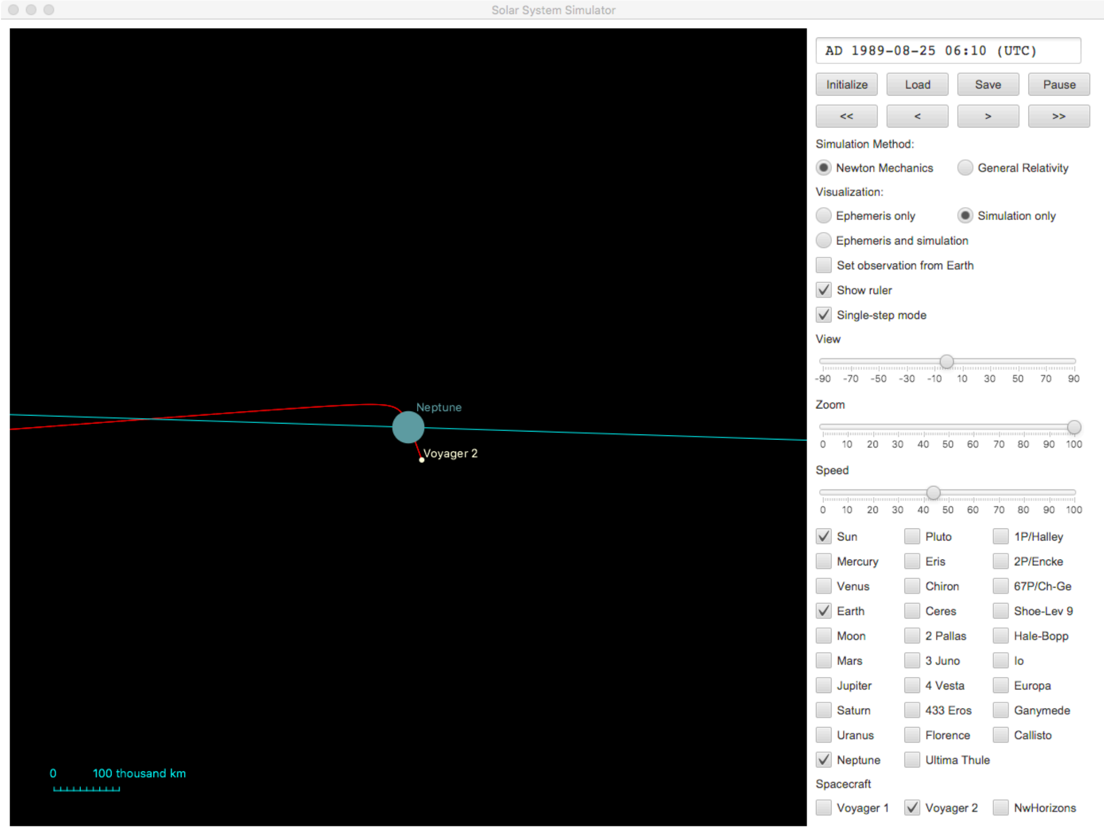
Voyager 1 passes Titan and approaches Saturn (November 12, 1980)



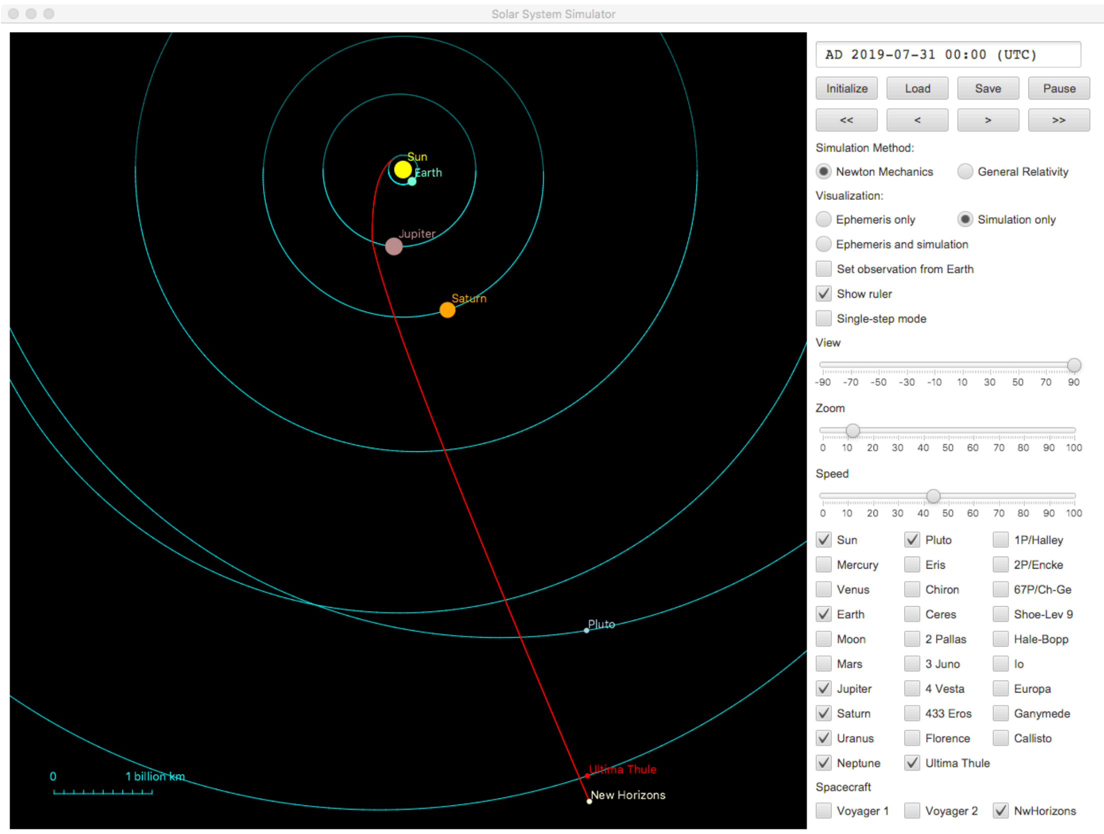
Voyager 2 passes Saturn (August 26, 1981)



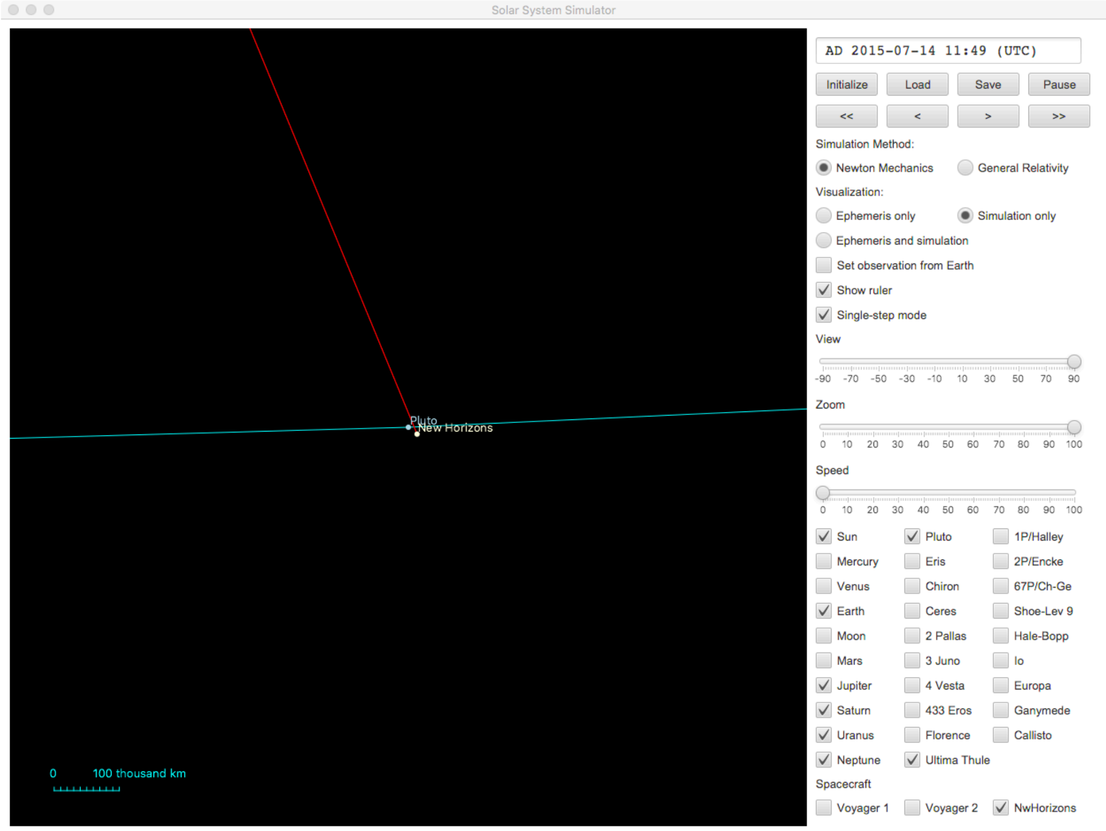
Voyager 2 passes Neptune (August 25, 1989)



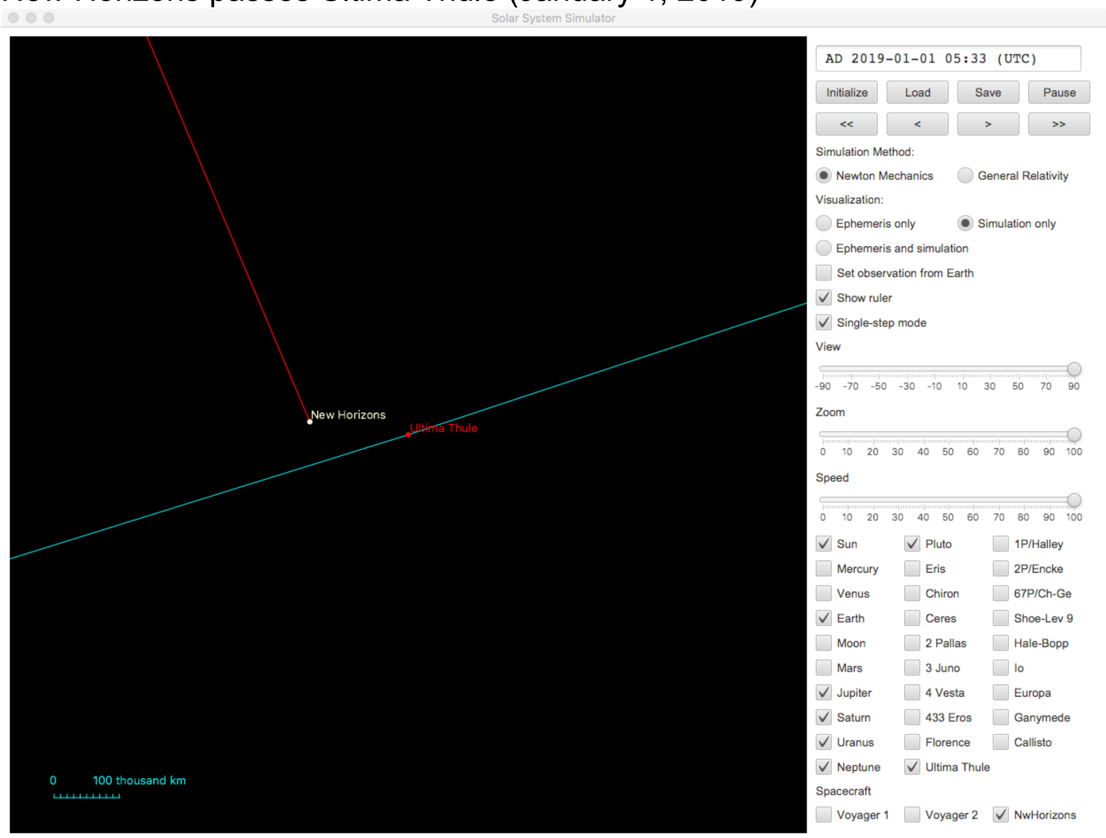
Trajectory of New Horizons. Simulation was started on January 10, 2006 before launch and finished in 2019.



New Horizons passes Pluto (July 14, 2015)

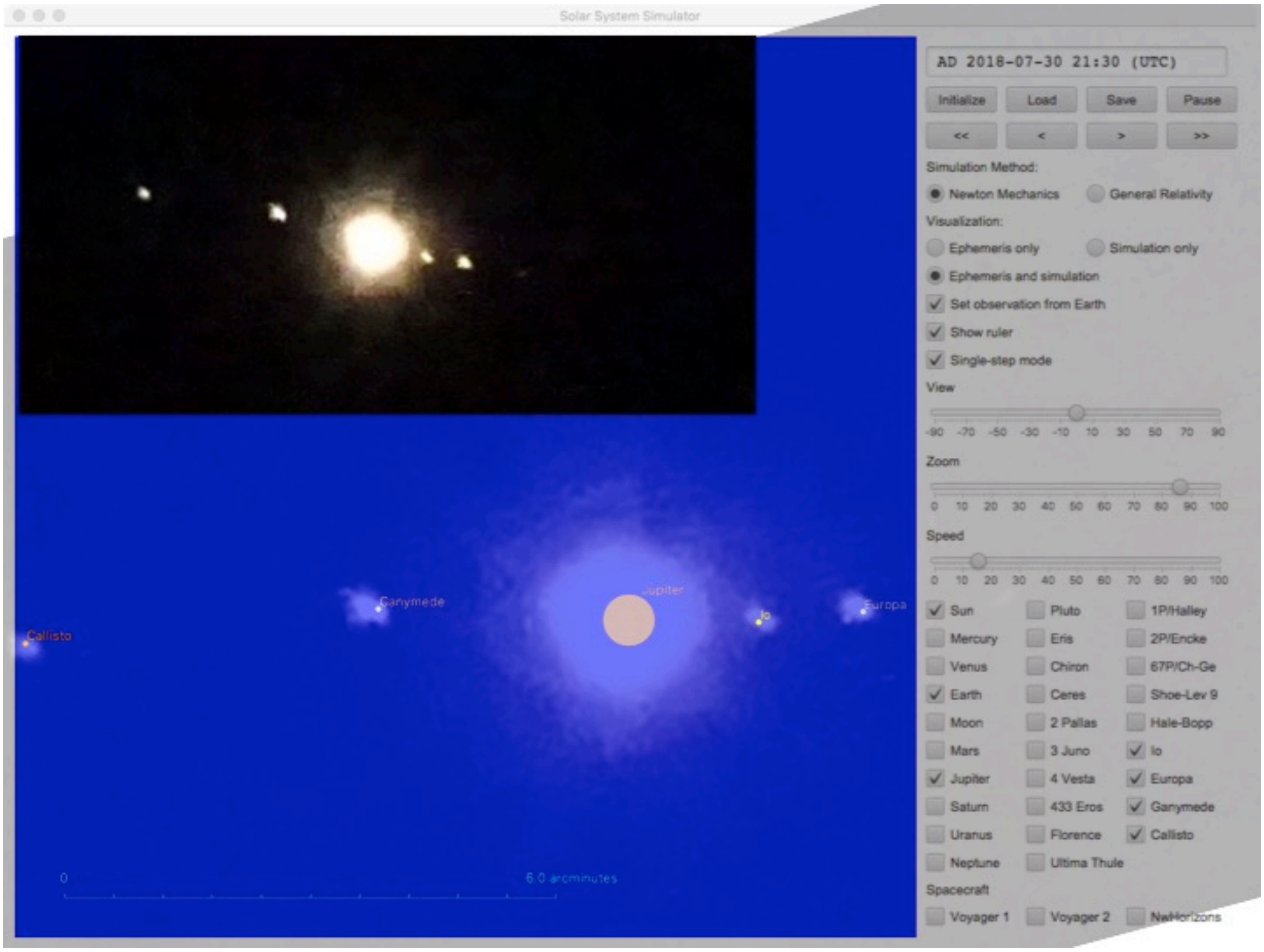


New Horizons passes Ultima Thule (January 1, 2019)



Jupiter and Galilean Moons as observed from the Earth (July 30, 2018).

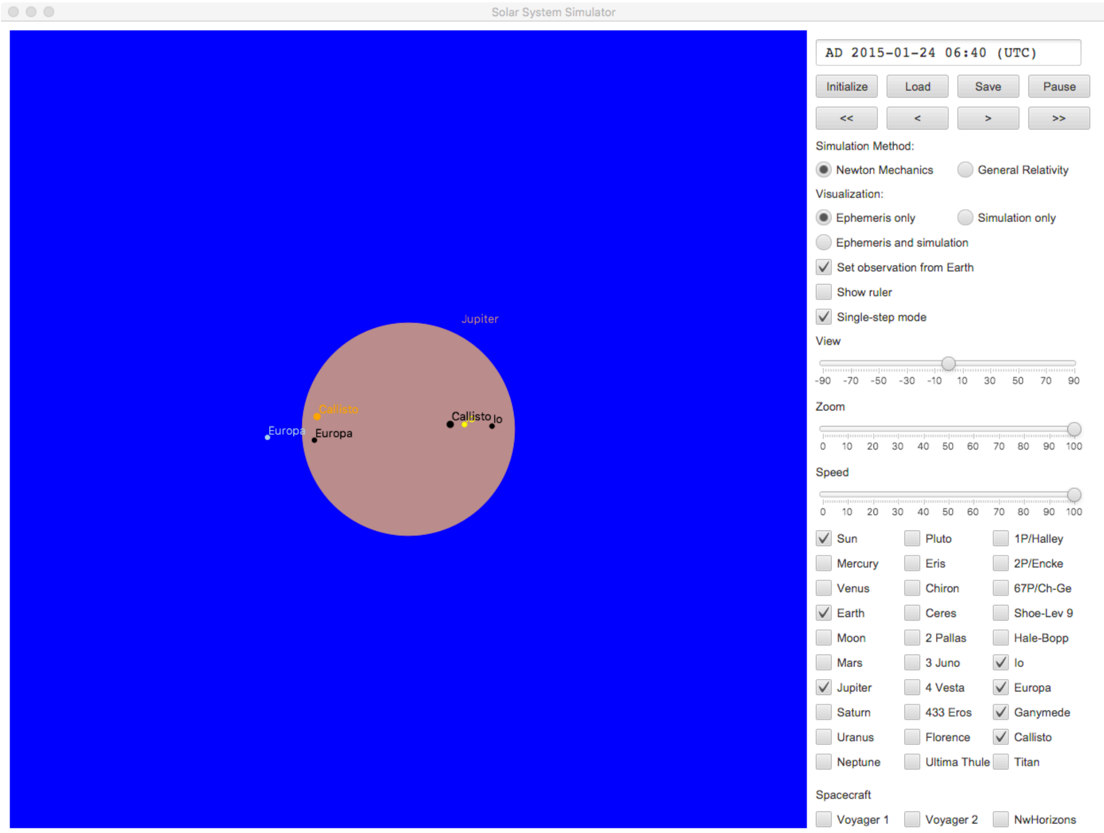
The inset is a photo taken with a digital camera on the evening of July 30, 2018 in Northern Spain. The photo is enlarged and overlaid with a screenshot of the Solar System Simulator of the same date and time. It can be observed that the locations of the Galilean Moons with respect to Jupiter are predicted pretty well by the simulator.

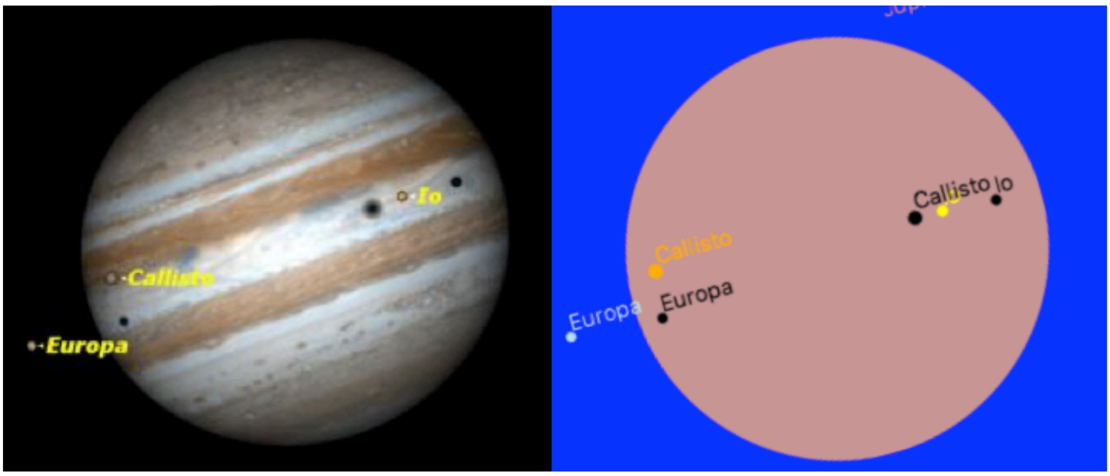


Shadows of Galilean Moons as observed from the Earth (January 24, 2015)

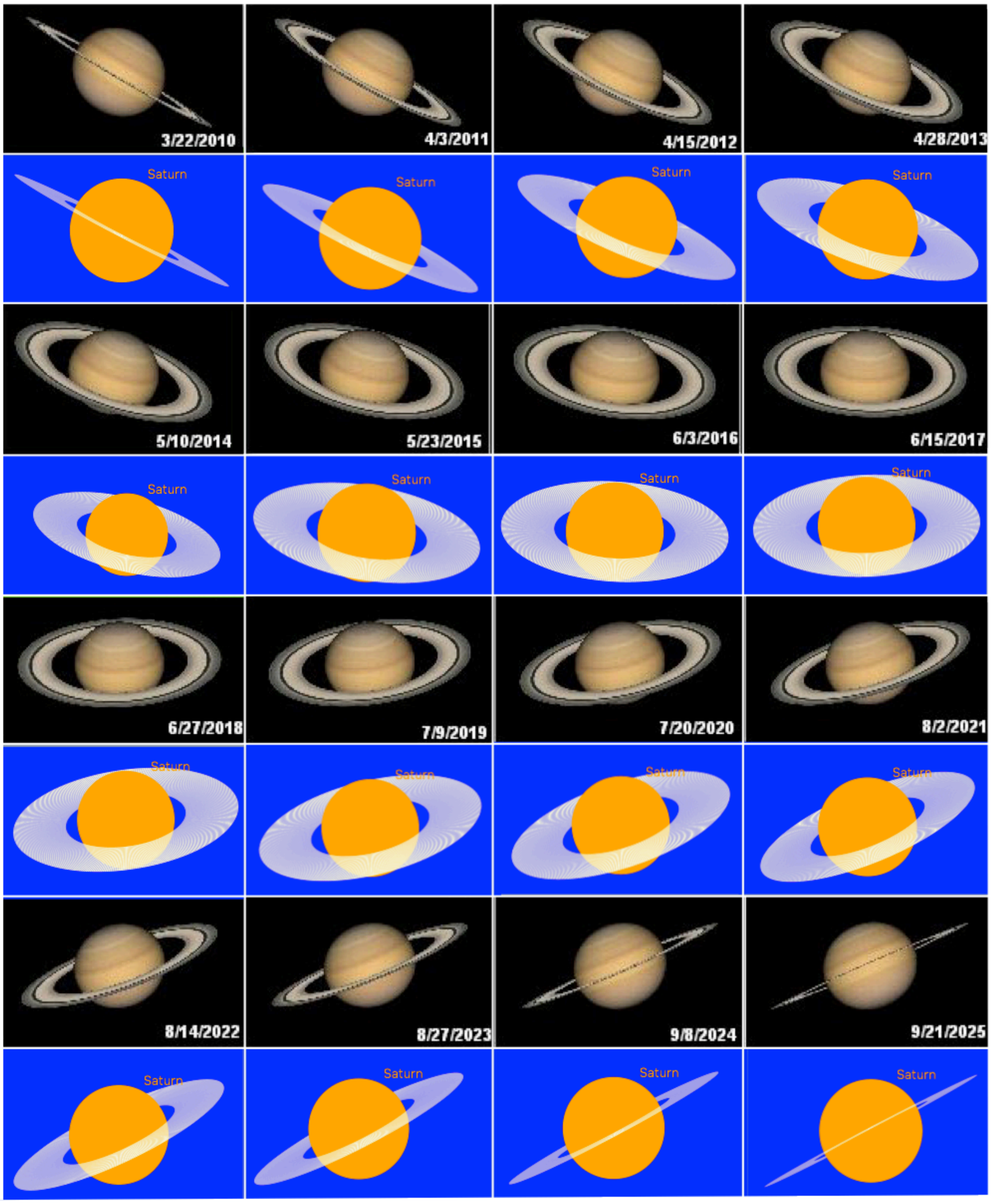
On January 24, 2015, Europa, Callisto, and Io transited Jupiter casting their shadows on the planet. Such an event rarely happens (see https://www.space.com/28342-jupiter-moons-rare-triple-transit.html)

Note that shadows of the Galilean Moons are only visualized when ‘Set observation from Earth’ is checked and Jupiter is selected.

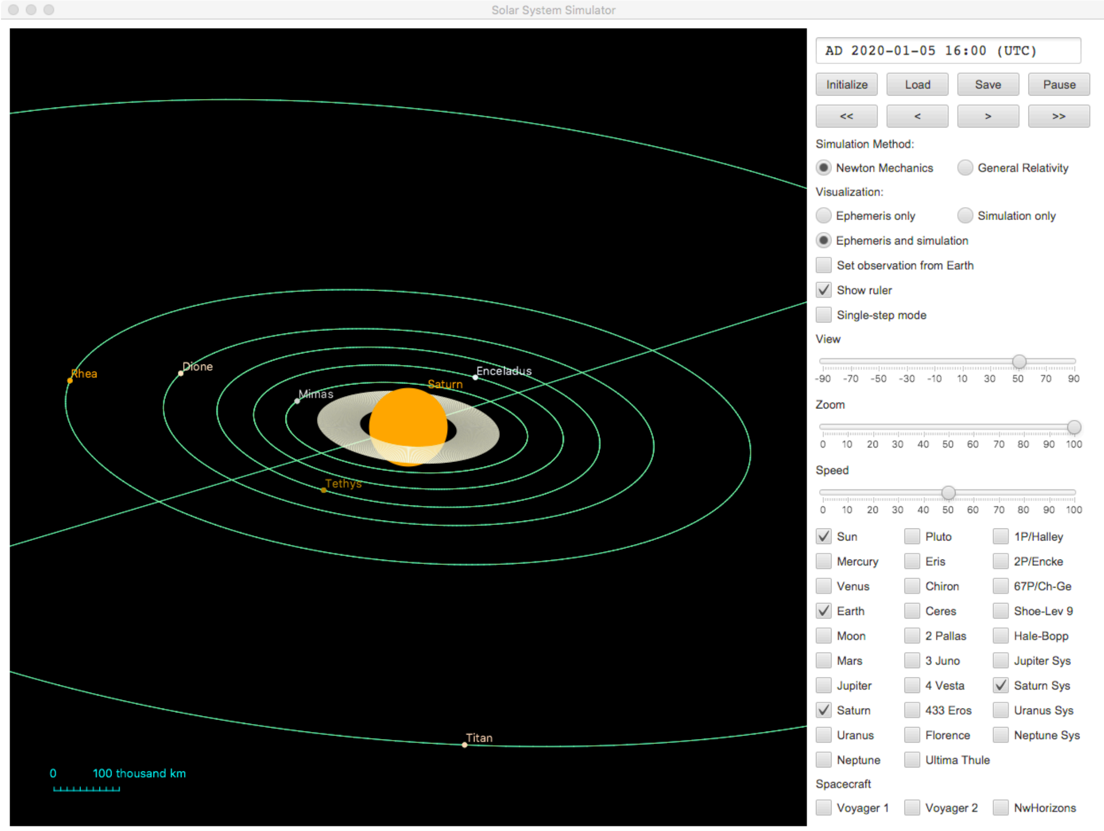




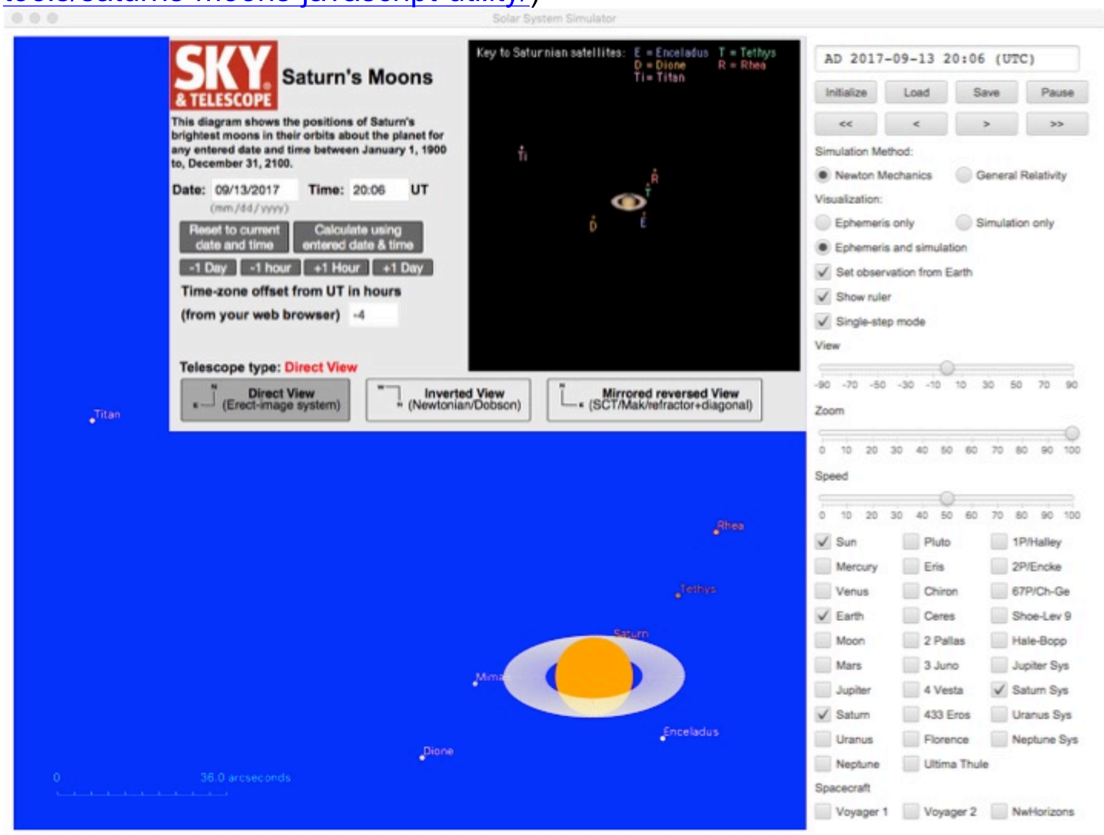
The rings of Saturn as observed from the Earth (dates ranging from 2010 through 2025).



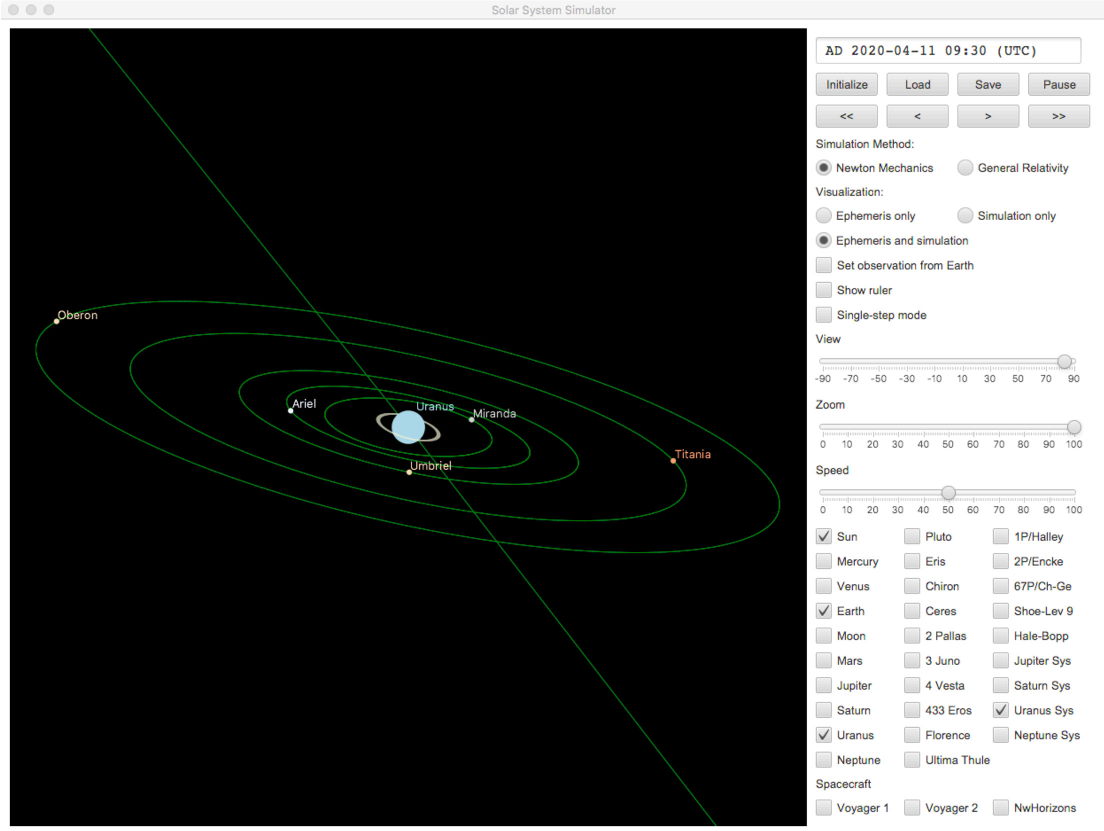
The moons of Saturn (January 5, 2020)



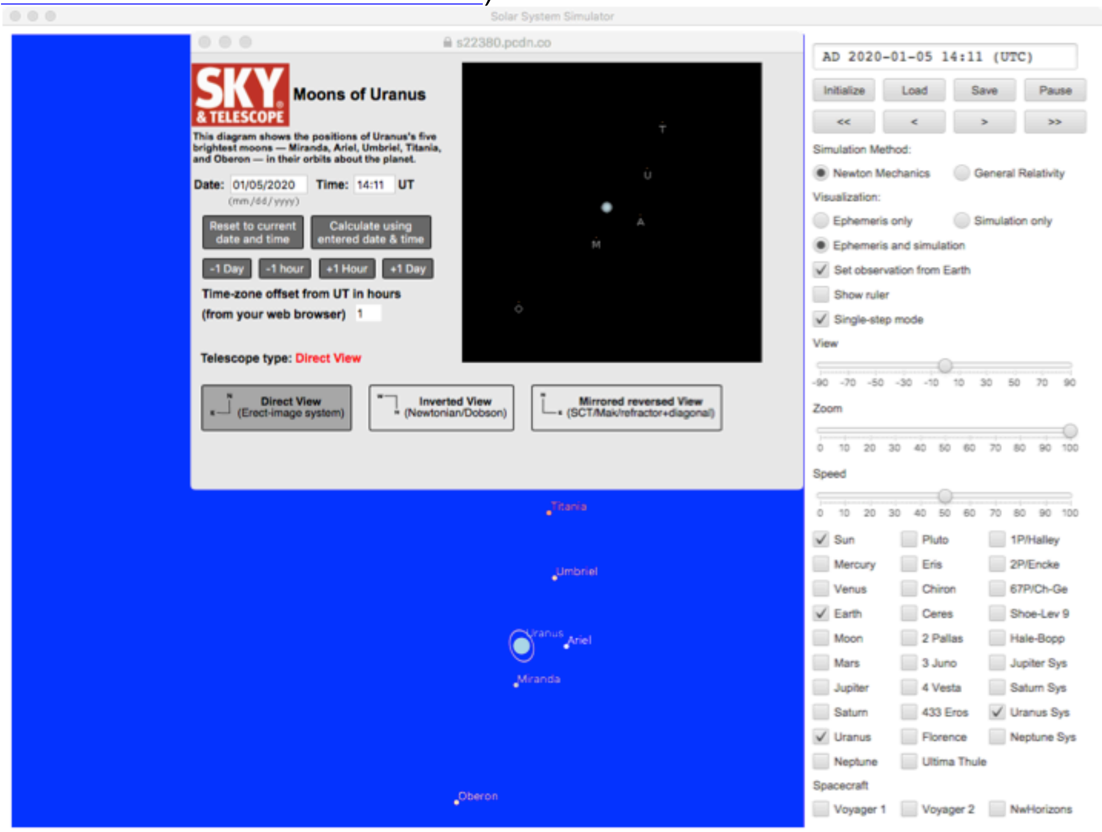
The moons of Saturn as observed from the Earth. The inset shows a screenshot from Sky & Telescope of the same date and time (see https://www.skyandtelescope.com/observing/interactive-sky-watching-tools/saturns-moons-javascript-utility/)



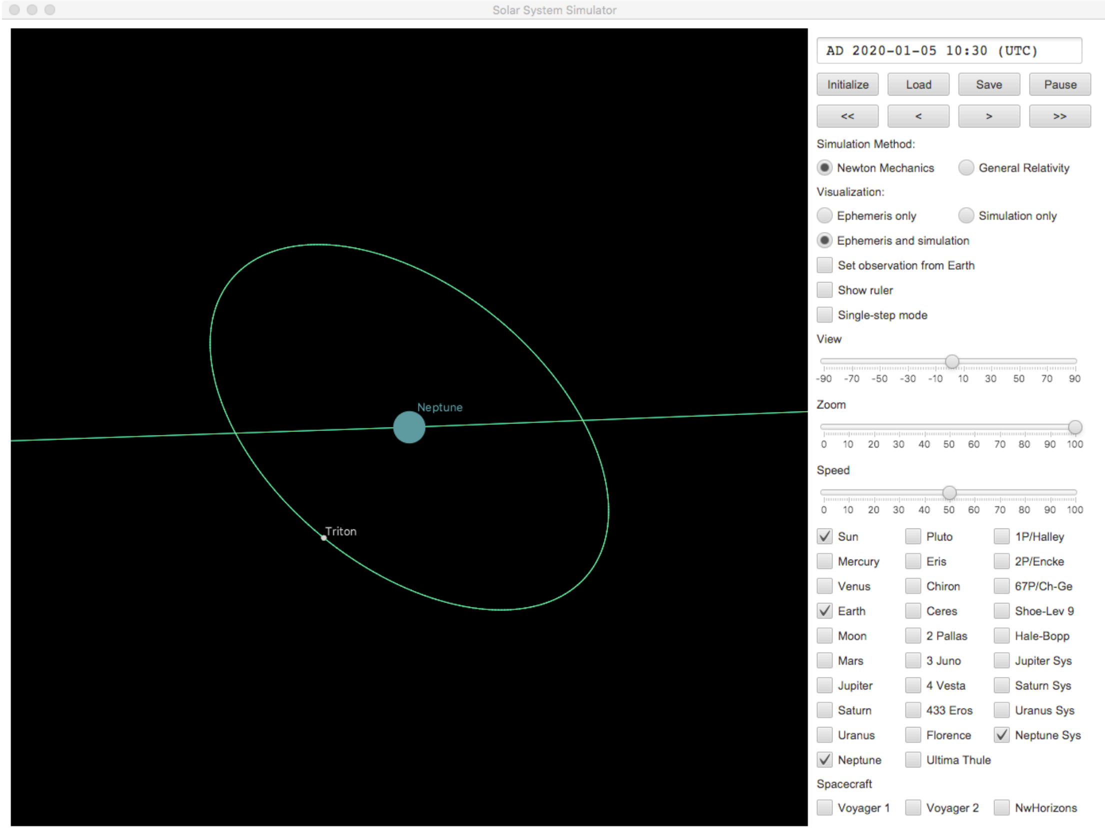
The moons of Uranus (April 11, 2020)



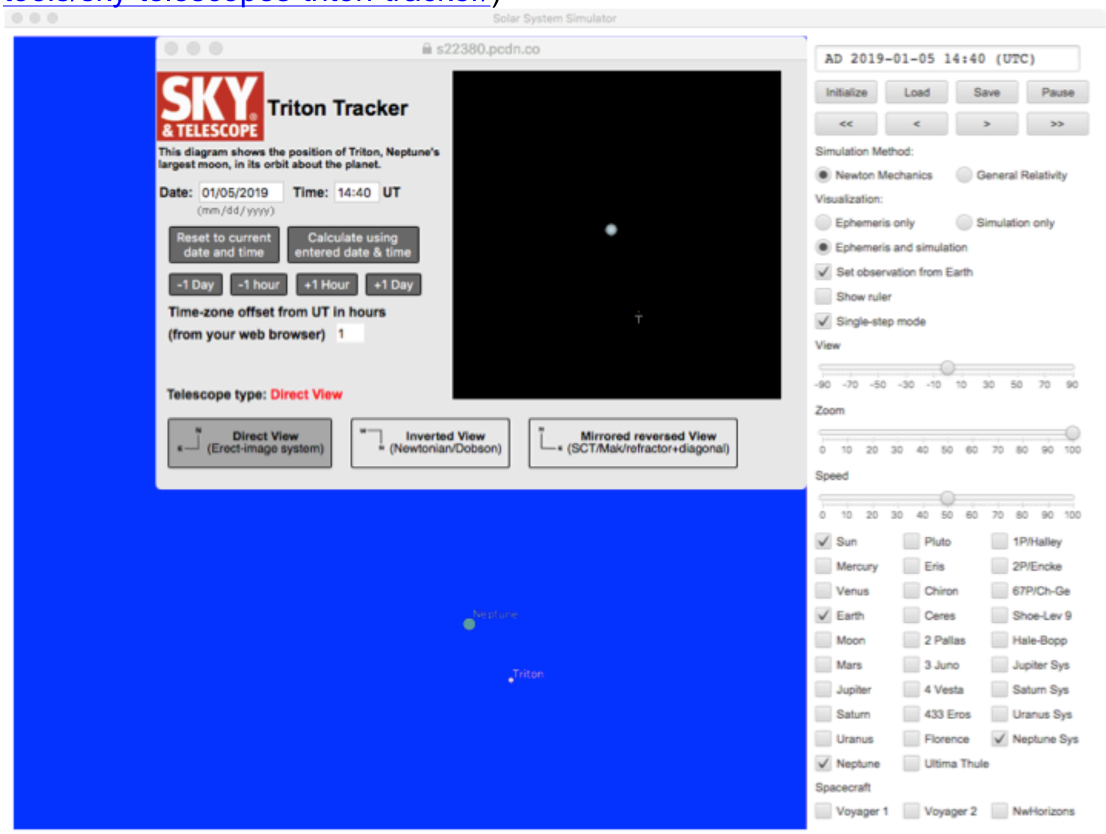
The moons of Uranus as observed from the Earth. The inset shows a screenshot from Sky & Telescope of the same date and time (see https://www.skyandtelescope.com/observing/interactive-sky-watching-tools/the-elusive-moons-ofuranus/)



Neptune and Triton (January 5, 2020)



Neptune and Triton as observed from the Earth. The inset shows a screenshot from Sky & Telescope of the same date and time (see https://www.skyandtelescope.com/observing/interactive-sky-watching-tools/sky-telescopes-triton-tracker/)



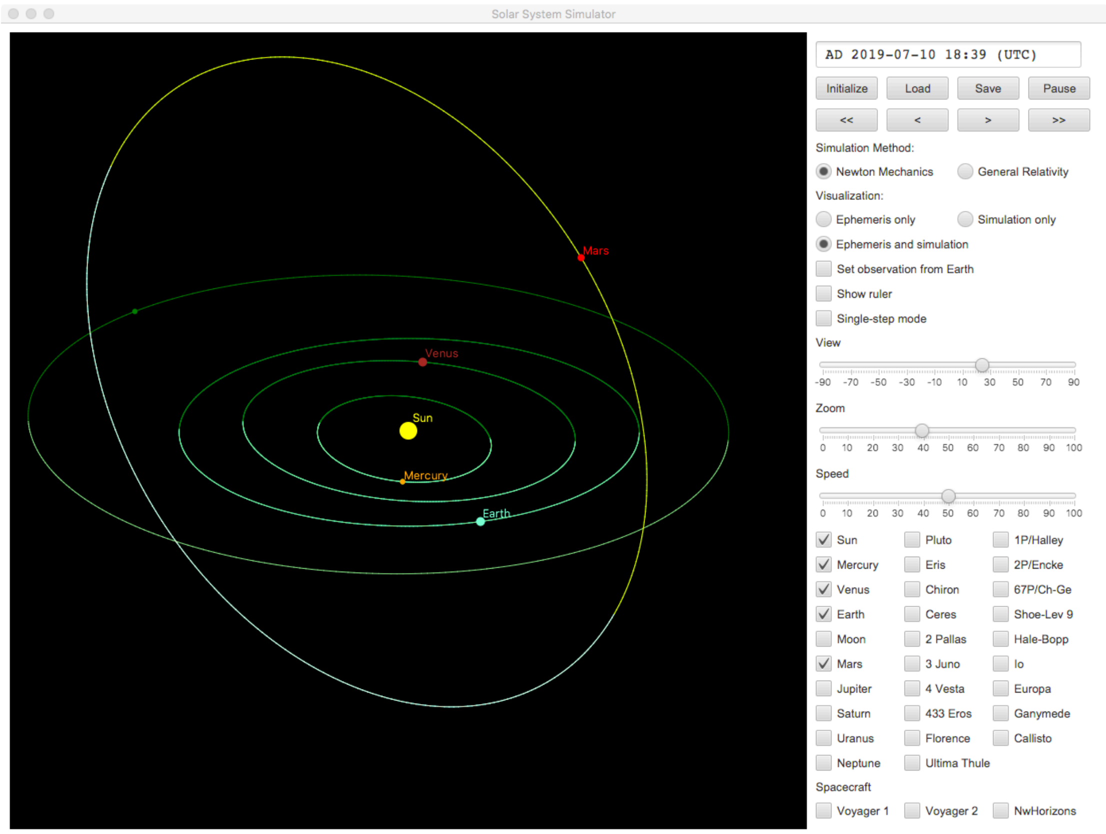
Inspecting and changing orbital elements

Orbits of planets and moons as well as spacecraft trajectories are described by orbital elements. The orbit itself is described by the semi-major axis, eccentricity, inclination, argument of periapsis, and the longitude of the ascending node. The location of the body within the orbit is determined by the mean anomaly. It is possible to compute position and velocity from the orbital elements and vice versa. Within the Solar System Simulator, the orbital elements of all bodies can be inspected and adjusted at will. Also, the mass of a body can be inspected and adjusted.

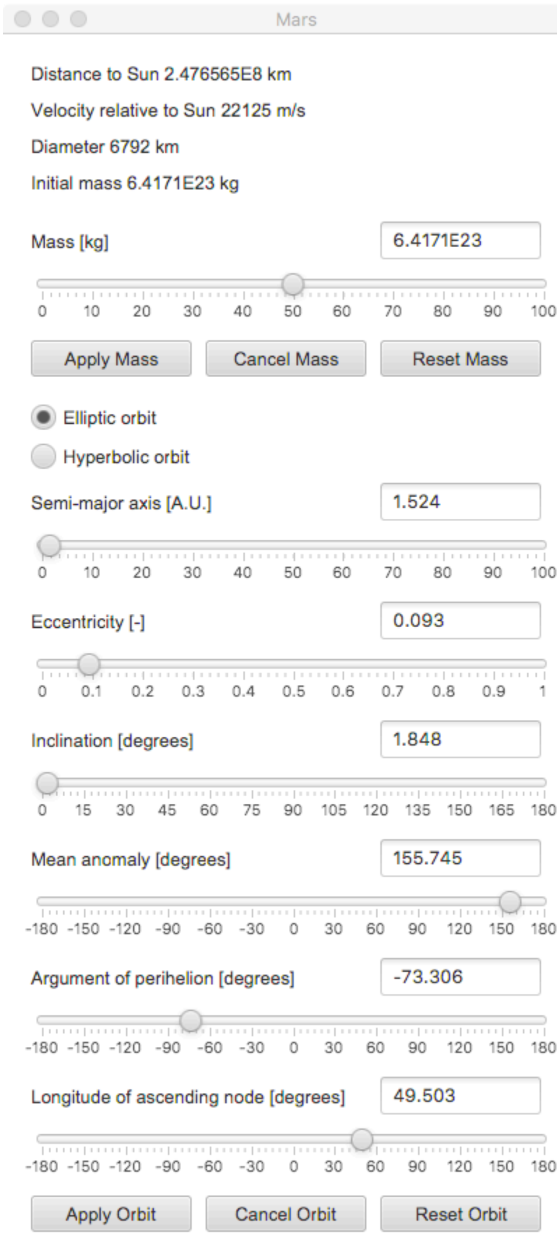
When right-clicking the check box (or the body name next to the check box), a new window appears in which the actual orbital elements of the selected body are shown. When the simulation is paused, orbital elements can be changed either by using sliders or by directly typing new numbers in the boxes. The yellow orbit corresponds with the current settings of the orbital elements. When clicking Apply Orbit, the new orbit and body position will be applied when the simulation is continued. To cancel the currently selected values, press Cancel Orbit, and to set the orbital elements to their actual values for the current date and time, press Reset Orbit.

In a similar fashion, the mass can be changed. Note that when the mass of the Sun is changed, the orbits of the planets are influenced as well.

Changing the orbital elements of Mars (July 10, 2019)



Orbital elements of Mars (July 10, 2019)



Orbital elements of Mars (changed)