Kepler's Laws and the Galilean Moons Prelab

MUST be completed before class on Friday, October 12

Students/groups who have not completed the prelab will not be able to participate in the lab

This prelab includes an individual portion and a group portion. You should complete the individual portion, which requires a ruler, a sheet of graph paper, and 4 different colored pens or pencils BEFORE meeting up with your lab partners.

Introduction

One of the great achievements of the astronomer Galileo Galilei was his identification of the four largest moons of Jupiter, now (appropriately) called the "Galilean moons" Io, Europa, Callisto and Ganymede. His observations were done with a small telescope and a great deal of patience. The observations that Galileo made of Jupiter, together with similar observations of Jupiter and the other planets in our solar system by Tycho Brahe, gave Brahe's apprentice Johannes Kepler the tools that he needed to develop the mathematical laws that we know today as Kepler's laws. You will find in this lab that you can use observations of Jupiter's moons to verify the basic principles described in Kepler's laws.

Procedure

25 images of Jupiter appear at the end of this prelab. Each shows what you would see through a small telescope (today a "small telescope" still means bigger and of better optical quality than the one that Galileo himself used, which was essentially a sailor's spyglass!) if you were to have observed Jupiter in the night sky on the date and time indicated in the upper right of each image and from a special location on Earth, this is what you would have seen. **The images have been color reversed, so bright things are dark and dark things are bright.**

To be completed by EACH group member BEFORE meeting with the rest of the group.

This prelab portion involves a number or measurements to be made with a ruler. The more carefully you make these measurements, the easier your life will be later.

1. Predict

In the space provided at the top of the "Individual Measurements" sheet later in this lab, explain the pattern of motion that you would expect a moon in orbit around Jupiter to make from our perspective here on Earth (note that we have essentially a "side view" of Jupiter with respect to the orbital plane of its moons). What would it look like if you were to graph the distance of each moon from Jupiter over time? It may help here to first consider what the orbits look like from a "top down" view, as though you were looking down on the solar system. Diagrams will also help you to visualize this. Use Kepler's laws to make an argument about how you might tell the difference between a moon that is close to Jupiter and one that is far away. Your prediction should be in the form of a full paragraph of complete sentences, and perhaps a diagram, to receive full credit ***but it does not need to be right***. Don't look up the answer – just make an attempt to reason it through yourself given what you already know.

2. Label the Moons

Now, let's turn to the data. If you examine them carefully, you will see that there are generally five objects in addition to Jupiter (the large, bright, banded object at the center) visible in the images. Your first task is to go through each of the images and label these objects 1-5. **Note that all five will not always appear in every image and that some of them will trade places over the course of the 50 hours of data shown, so look carefully. If you called one object "object 2" in the first frame, you should call it "object 2" throughout even when it switches places with other objects.**

As you go through the images, you should also place a dot at the center of Jupiter in each image using a ruler.

2. Measure

Now, go through and measure the distance to each moon in millimeters from **the center of Jupiter** that you marked in the last step. Record each value in the table at the end of this lab. **Mark all distances where the object is to the right of Jupiter as positive and all where the object is to the left of Jupiter as negative.**

Once you have completed the three steps above, you can meet up with your lab partner(s) to complete the second part.

To be completed by ALL group members TOGETHER once EVERYONE has finished their Individual Measurements

1. Collaborate

Each of your group members should have a completed table of measurements and a prediction of what pattern moons in orbit around Jupiter should make. Because you each completed this portion individually, the naming of your objects (1-5) may not be consistent. Begin by agreeing on an object naming scheme (which object is #1, etc.). Each group member should fix their individual measurements table according to this new scheme by changing the object numbers in the first row of the table where necessary. All individual group members should write their exoplanet names on their individual measurements and hand that sheet in with the rest of the prelab.

2. Average

One basic principle of science is that independent measurements that are averaged together are generally more reliable than single measurements. Average the measurements of your group members together for each moon at each time step and fill in the "group table" with these averages. This is where it is important that you have relabeled your moons to the same numbering scheme as your other group members. If you were all careful, your measurements should be similar. If they are significantly different between group members, you should check them before proceeding. Perhaps the numbering scheme is off for one group member, or perhaps you don't agree which object is which when they switch places. Discuss all discrepancies and agree as a group before proceeding.

3. Plot

Compile all of the data from Step 2 and use it to make a chart (one per group, but all group members need to assist and should not just be watching one person do all of the work!) of the location of each moon relative to Jupiter. Your graph should follow the following guidelines:

1. The x axis should show the distance from Jupiter in mm, and should include positive (to the right of Jupiter) and negative (to the left of Jupiter) values.
2. The y axis should be placed at the location of Jupiter (an x axis value of zero) and should show the time (from hour 1 to hour 50).
3. You should mark the location of each of the five objects at each time step with a small colored dot. Use five different colors for the five different objects **and make a legend in one corner of your graph showing which is which**.
4. Connect the path of each moon with a dashed line in that same color.
5. Follow the general guidelines for good graphs: **use your space wisely** (your chart should take up the whole page!), include a title and axis labels, etc.

4. Debate Predictions

Discuss and debate your individual predictions from step 3 in the individual portion. On the back of the group measurements sheet, in several paragraphs of complete sentences, note where you agreed or disagreed in your predictions and compare them to what was actually observed. What does your group think we can learn from this graph? What questions do you have about it (record at least two)?

Exoplanet Name**:** _____

Individual Measurements – Hand in one per group member

Individual Prediction:

This portion must be completed by EACH group member BEFORE you meet as a group.

	Object 1	Object 2	Object 3	Object 4	Object 5
Image 1					
Image 2					
Image 3					
Image 4					
Image 5					

	Object 1	Object 2	Object 3	Object 4	Object 5
Image 6					
Image 7					
Image 8					
Image 9					
Image 10					
Image 11					
Image 12					
Image 13					
Image 14					
Image 15					
Image 16					
Image 17					
Image 18					
Image 19					
Image 20					
Image 21					
Image 22					
Image 23					
Image 24					
Image 25					

Exoplanet Names**:** _____

Group Table – Hand in one per group

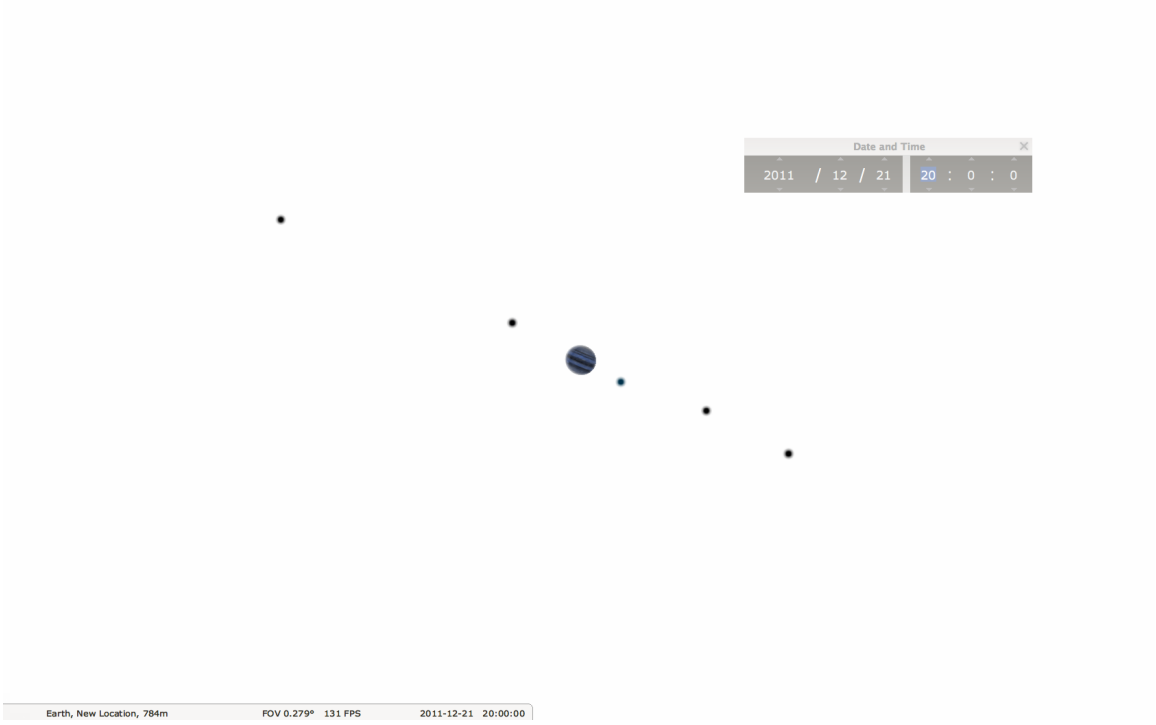
This portion should be completed by the group together, with one copy handed in per group.

	Object 1	Object 2	Object 3	Object 4	Object 5
Image 1					
Image 2					
Image 3					
Image 4					
Image 5					
Image 6					
Image 7					
Image 8					
Image 9					
Image 10					
Image 11					
Image 12					
Image 13					
Image 14					
Image 15					
Image 16					
Image 17					
Image 18					

	Object 1	Object 2	Object 3	Object 4	Object 5
Image 19					
Image 20					
Image 21					
Image 22					
Image 23					
Image 24					
Image 25					

Group Prediction:

Kepler's Laws and the Galilean Moons
AST 112
Data Sheet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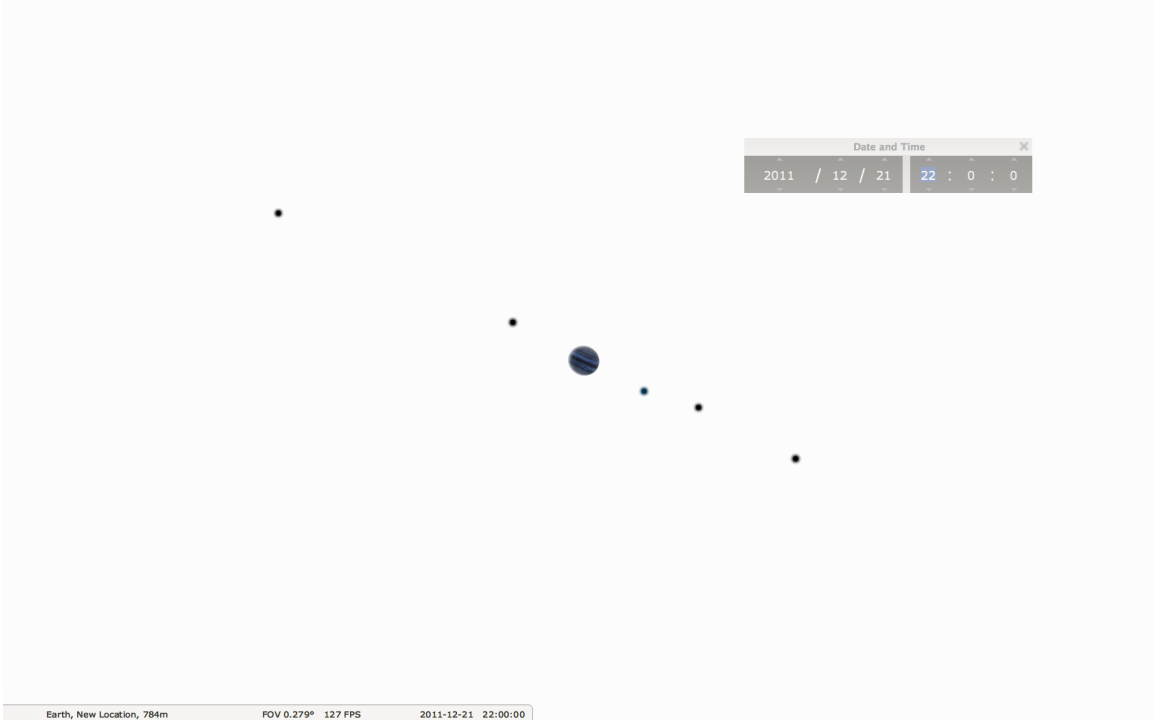
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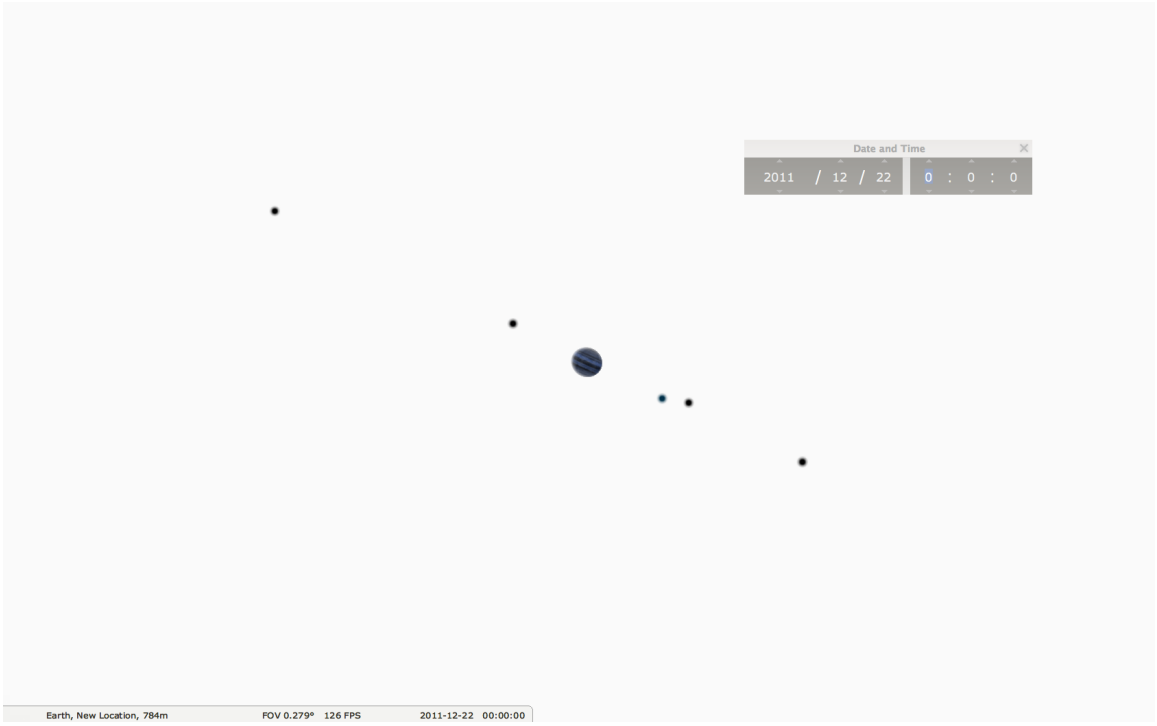
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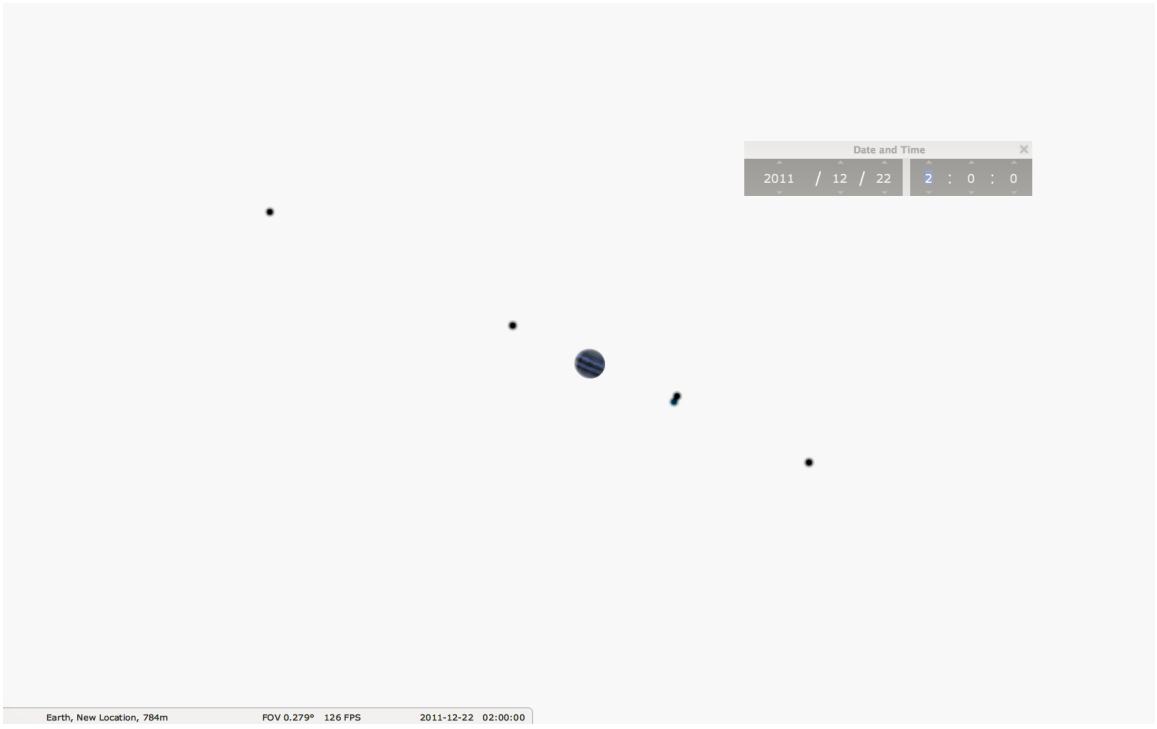
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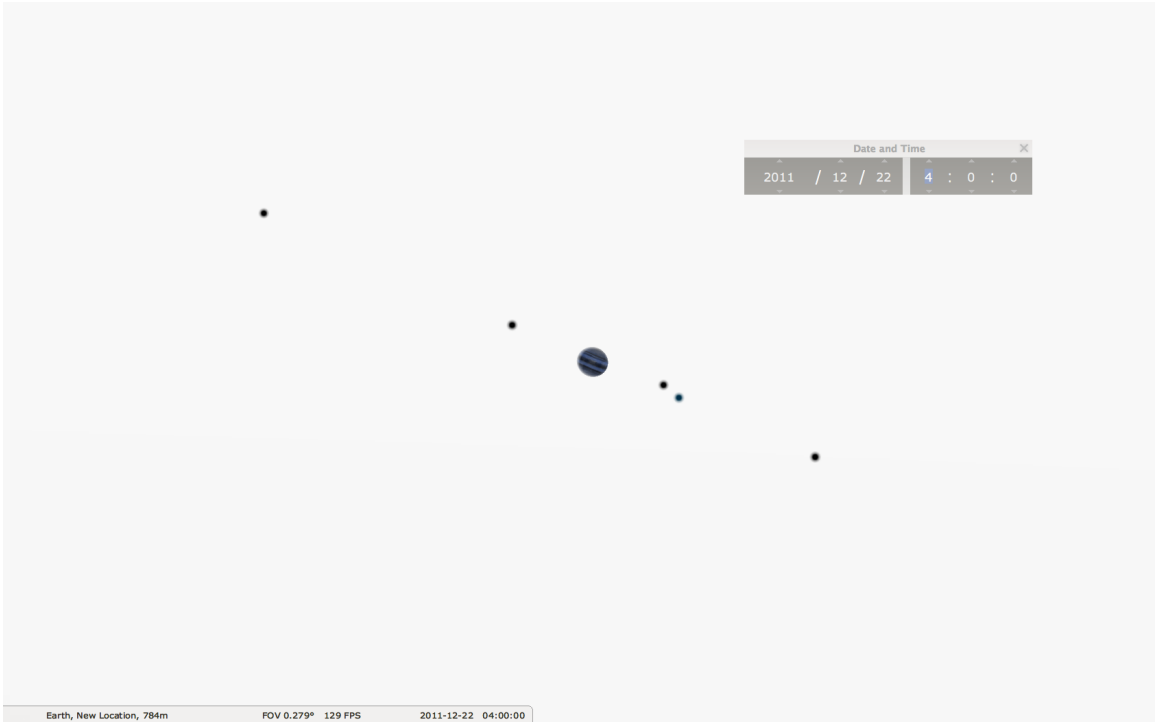
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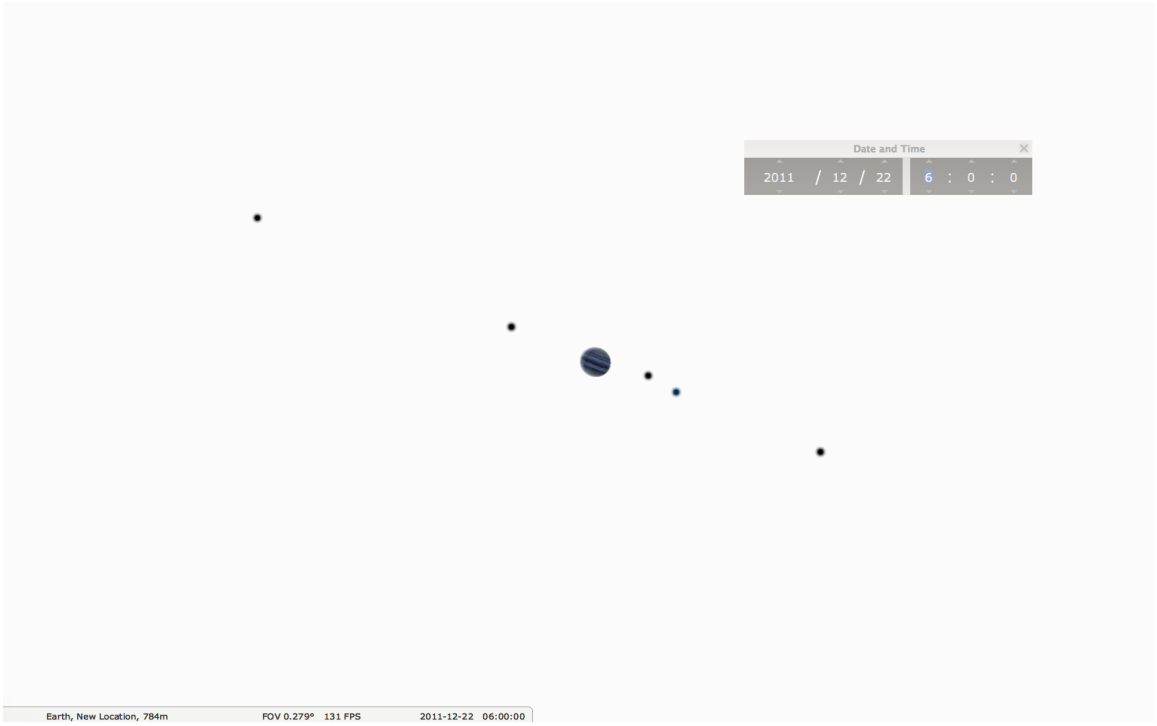
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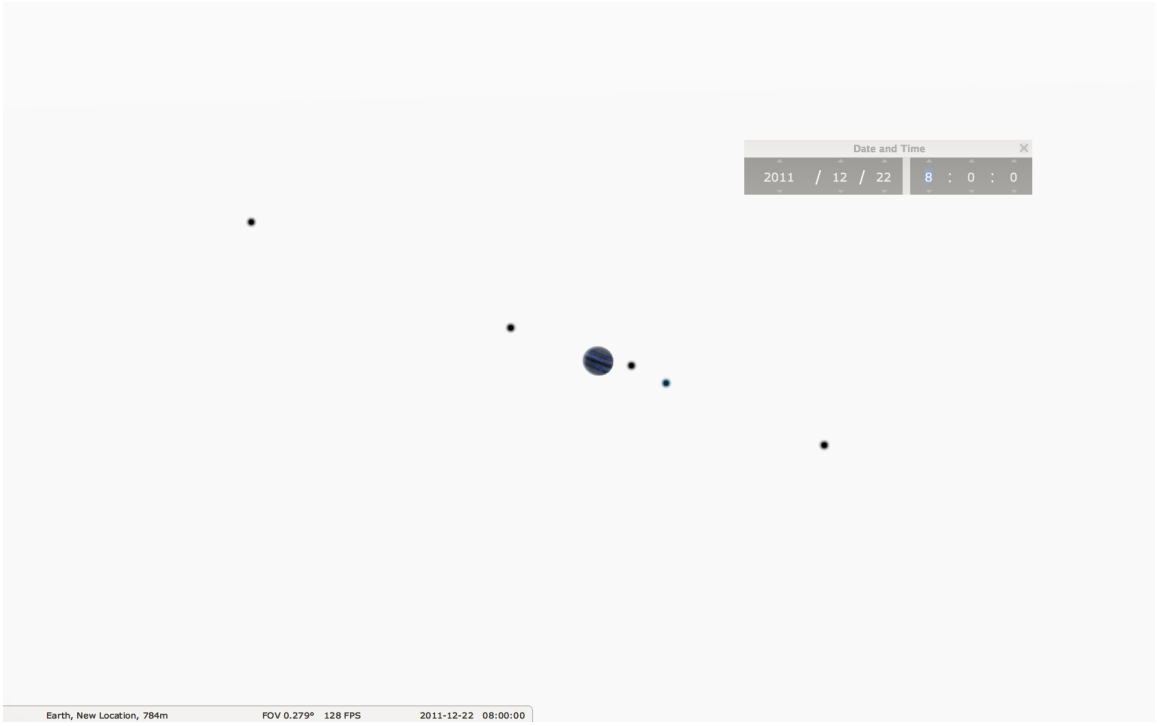
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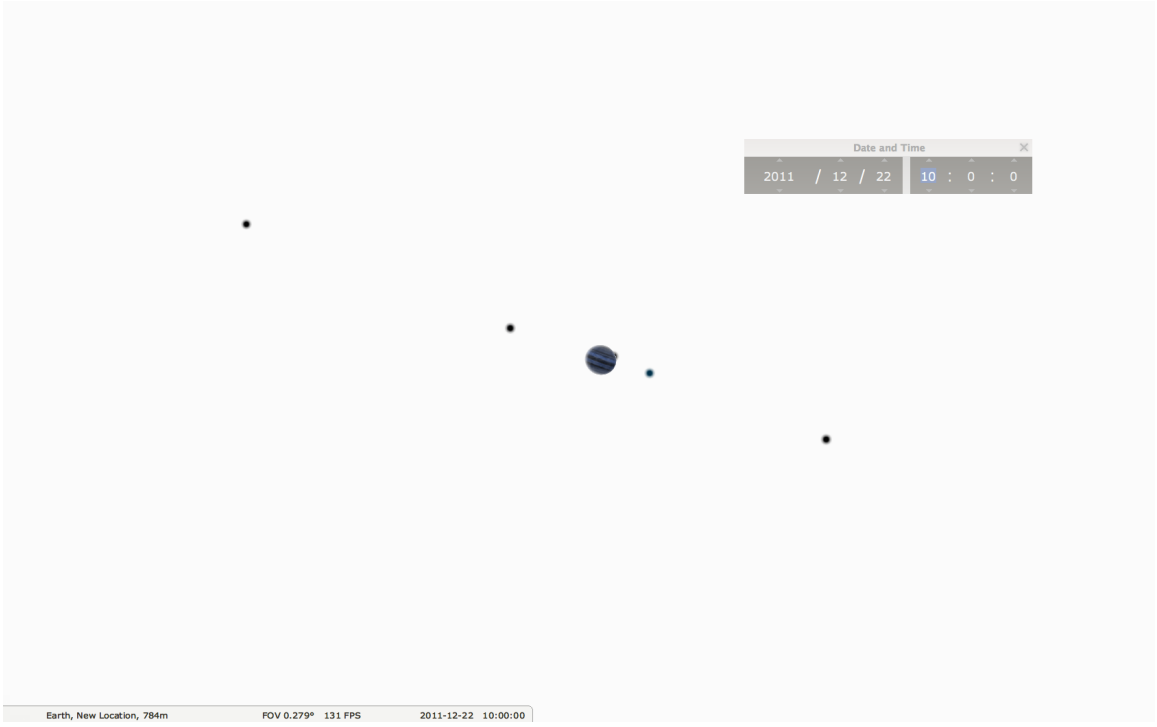
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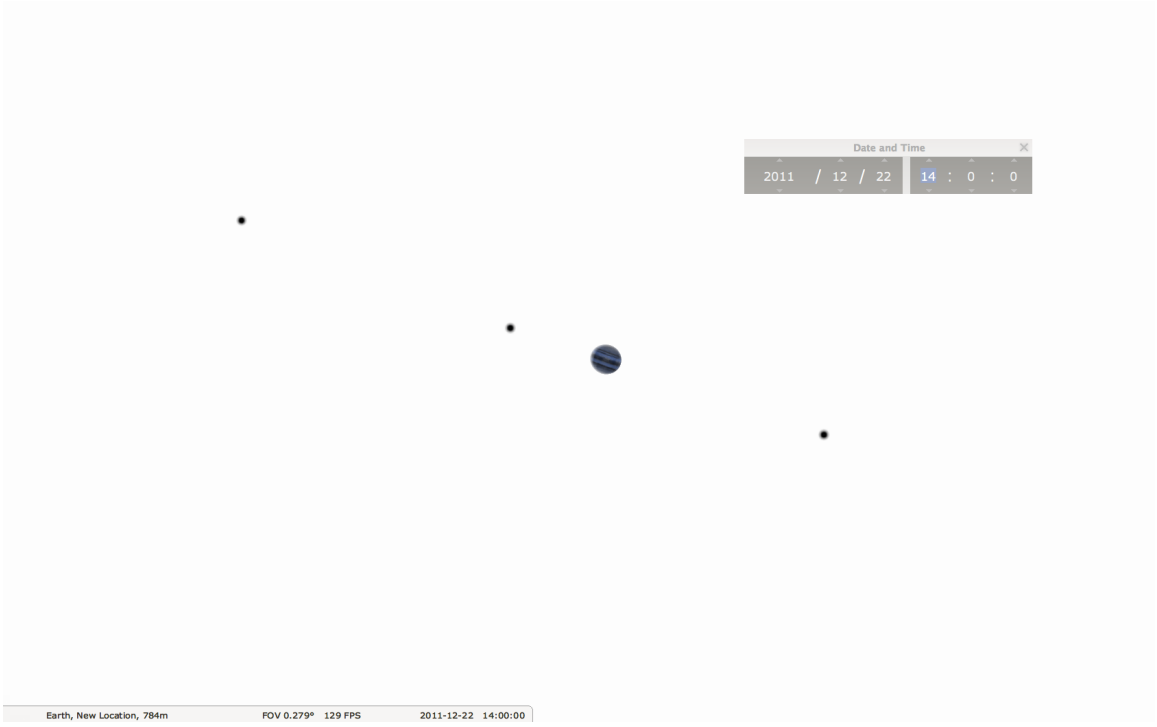
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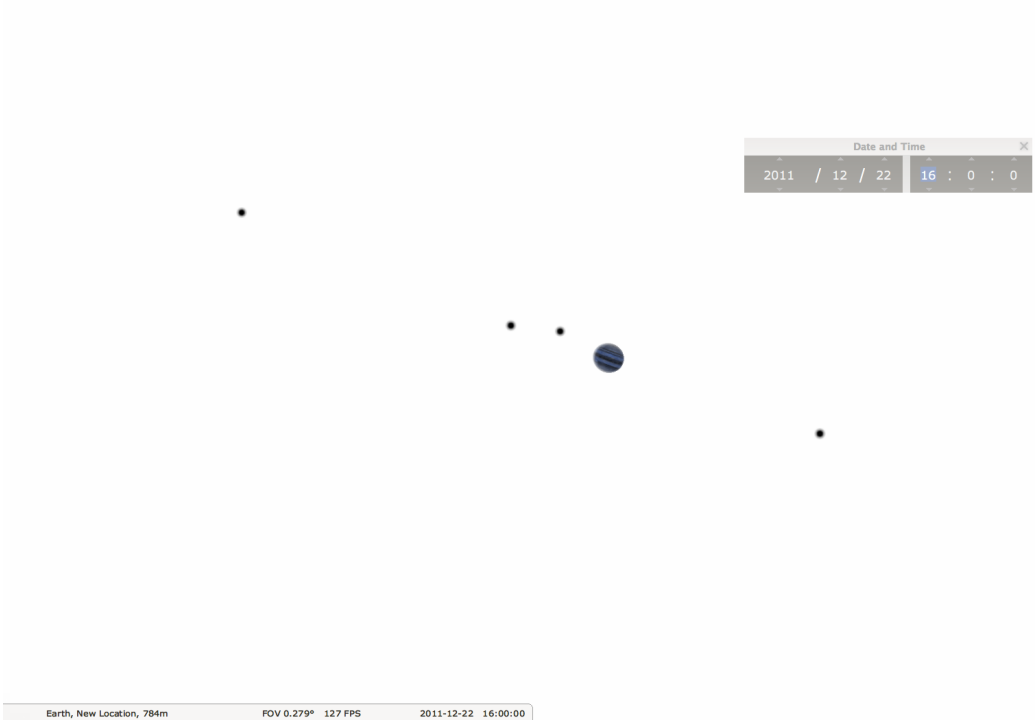
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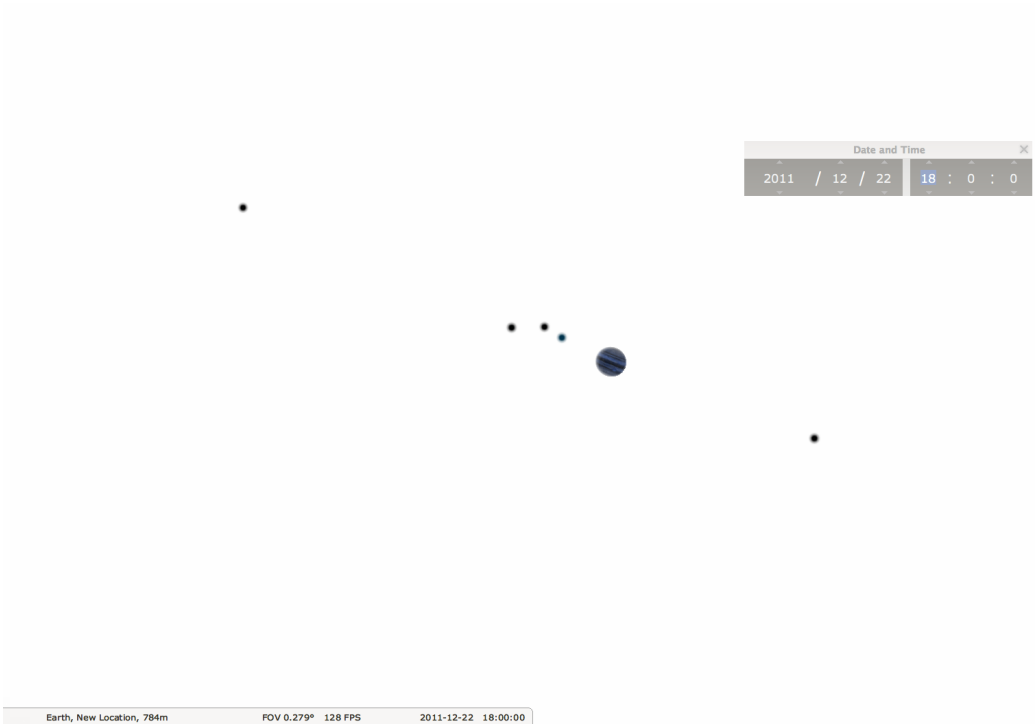
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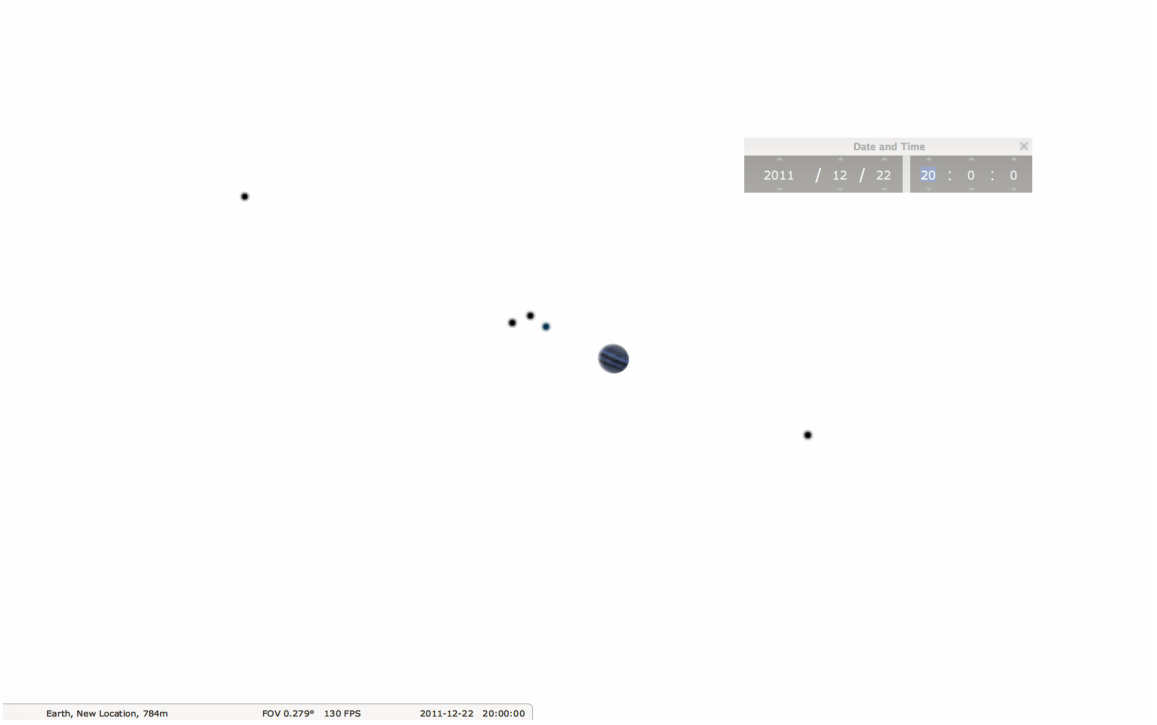
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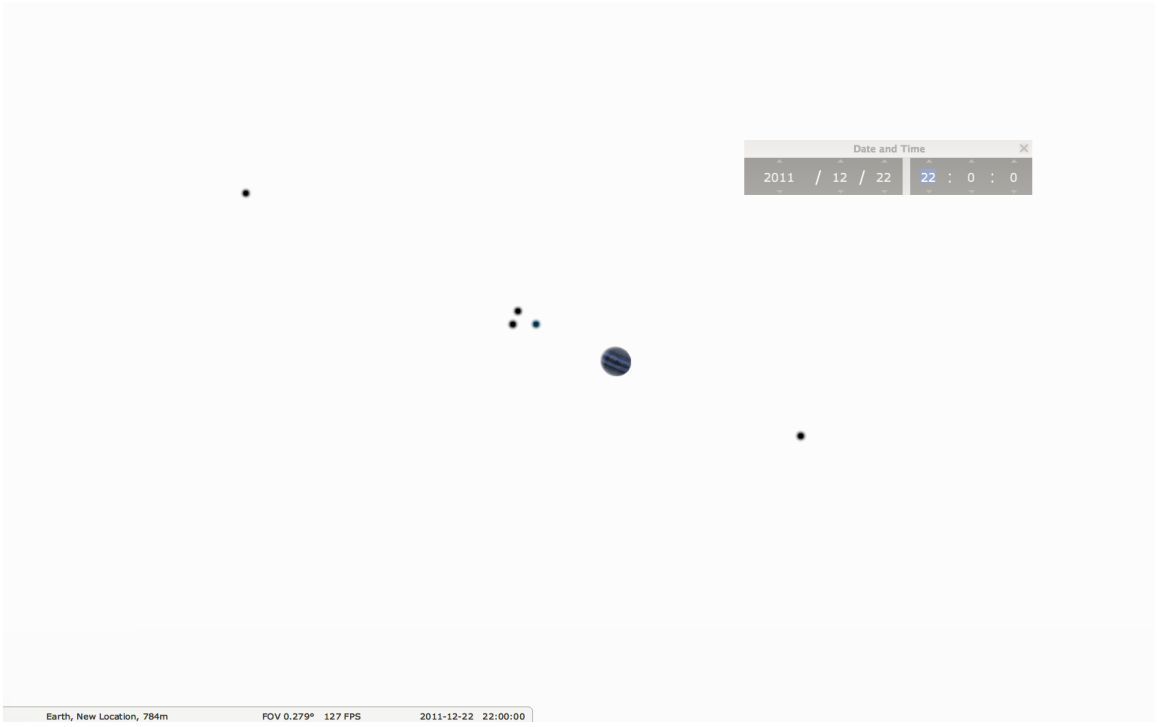
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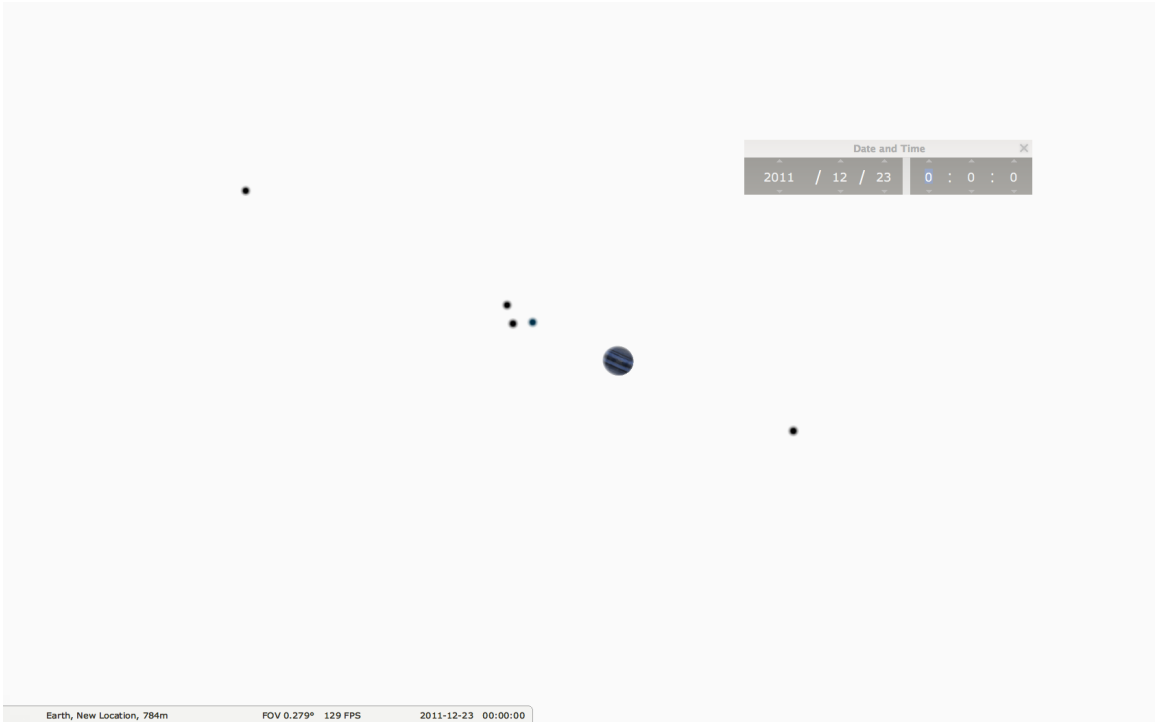
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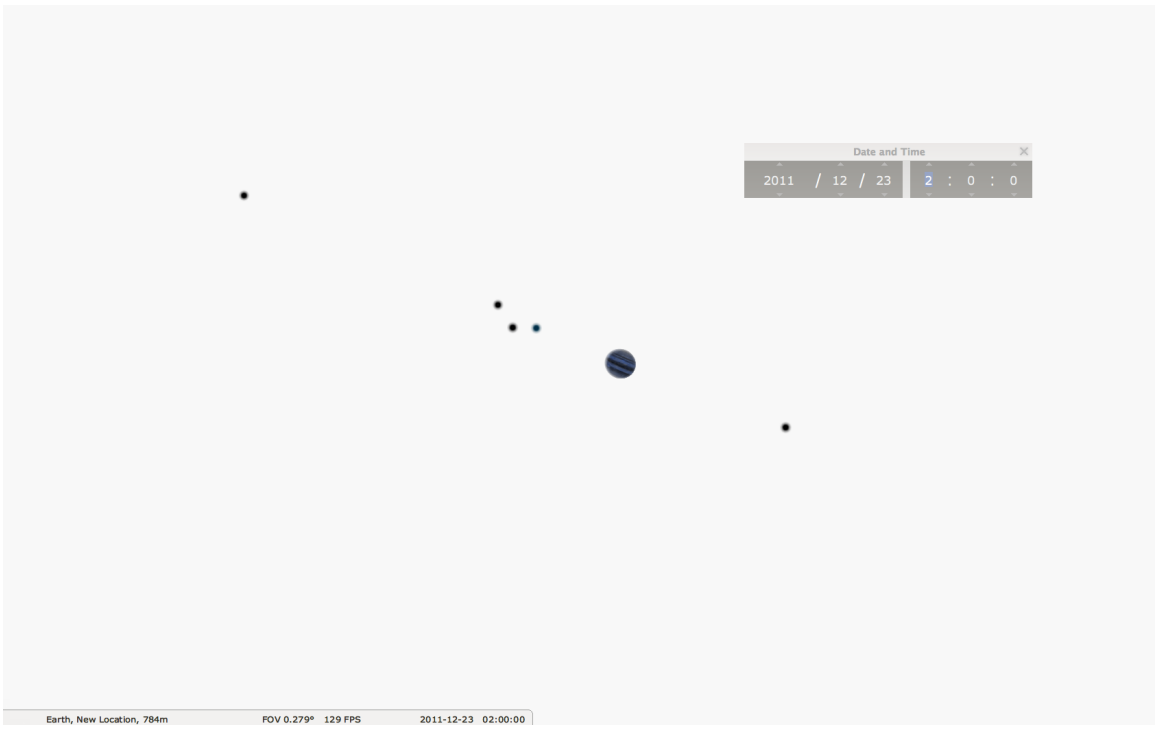
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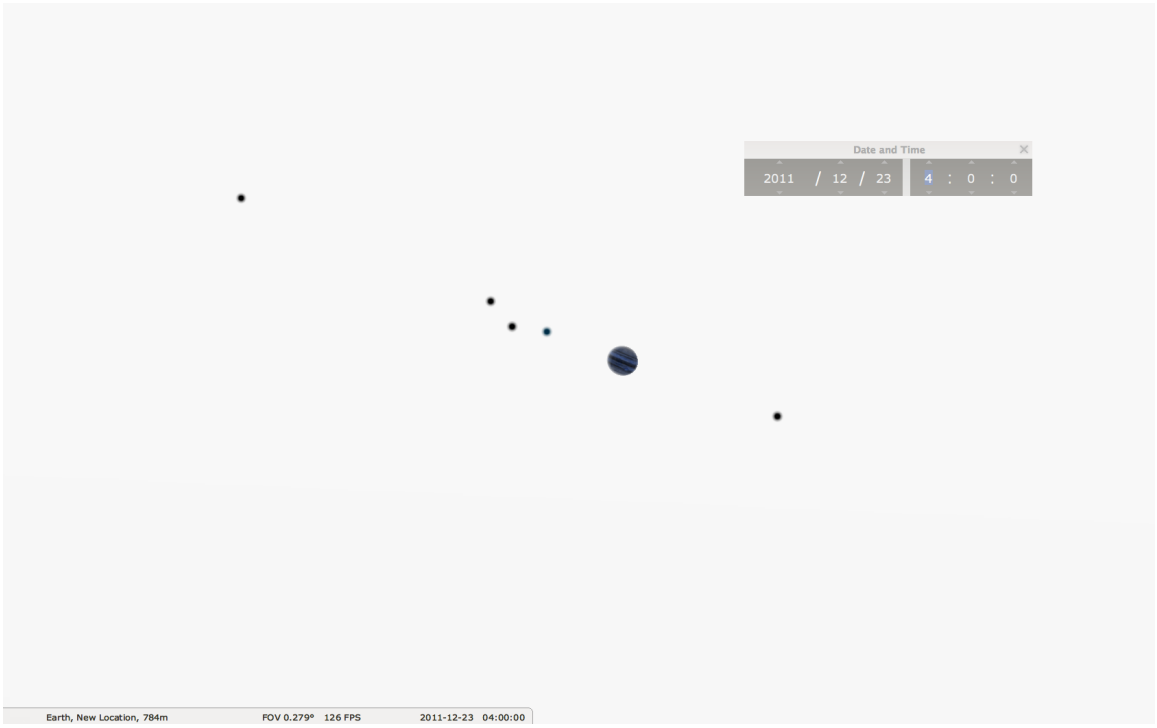
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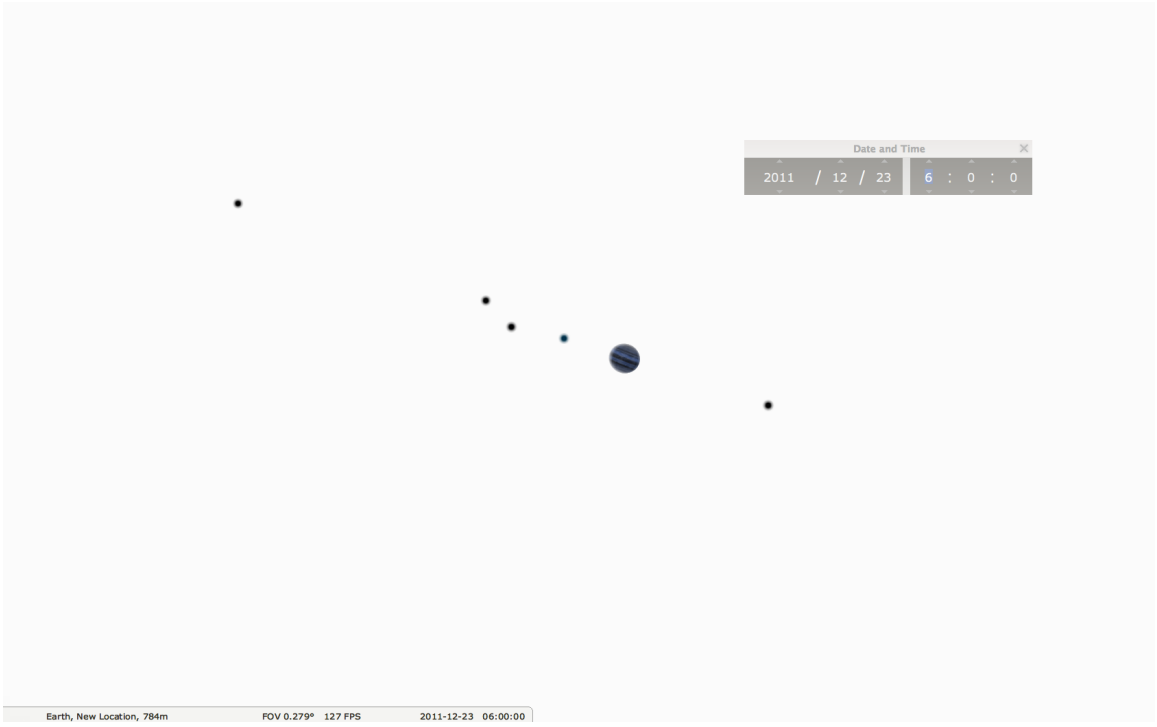
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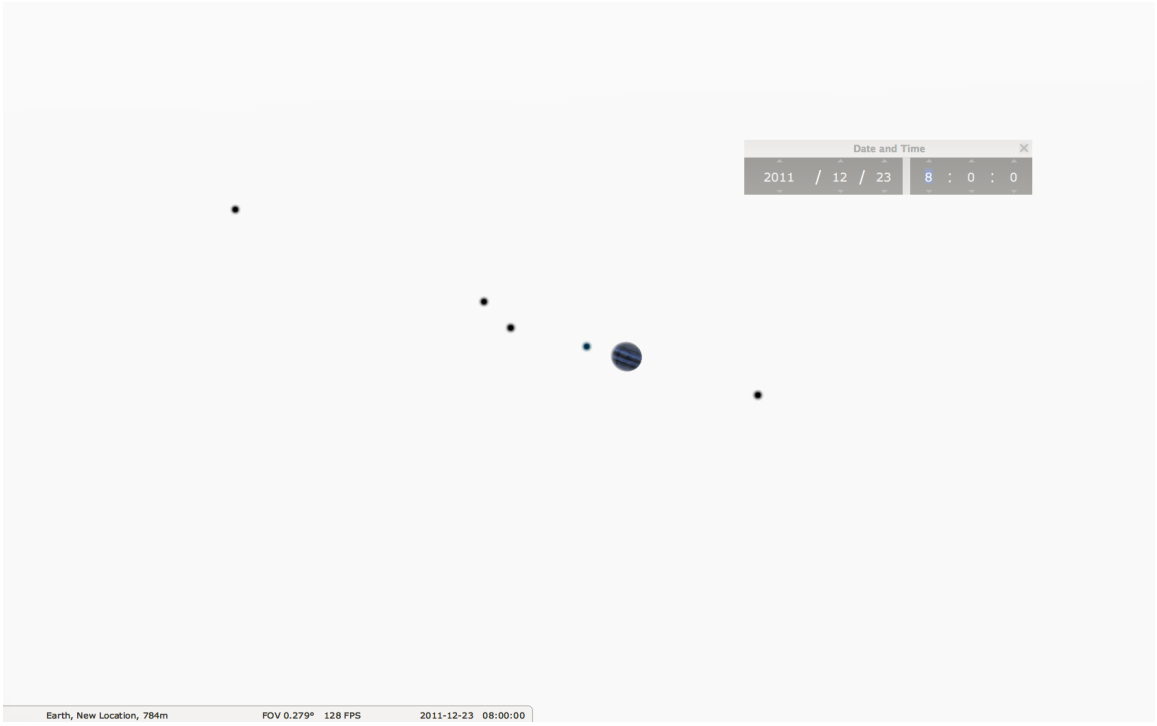
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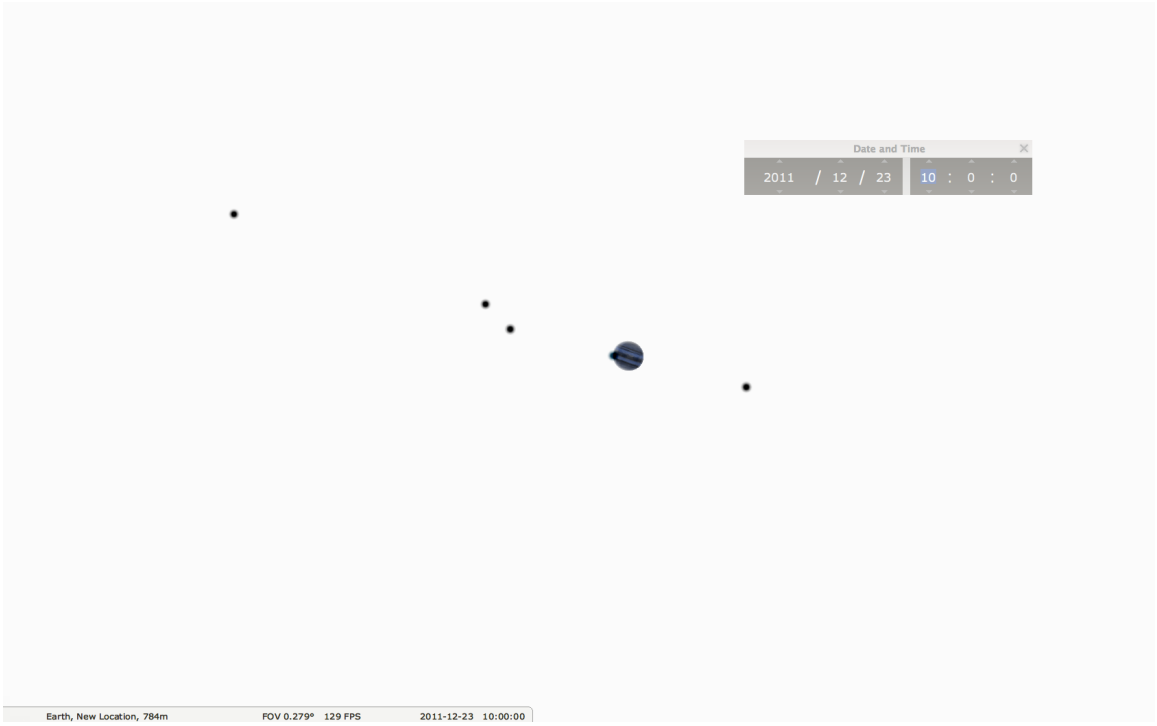
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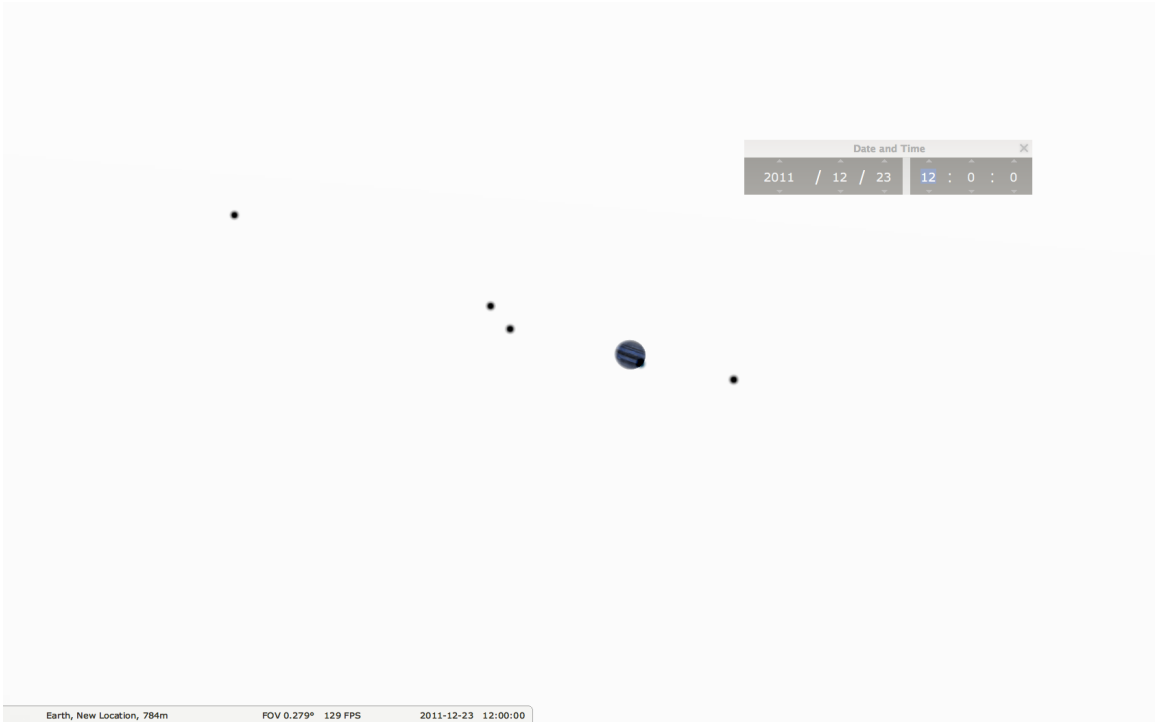
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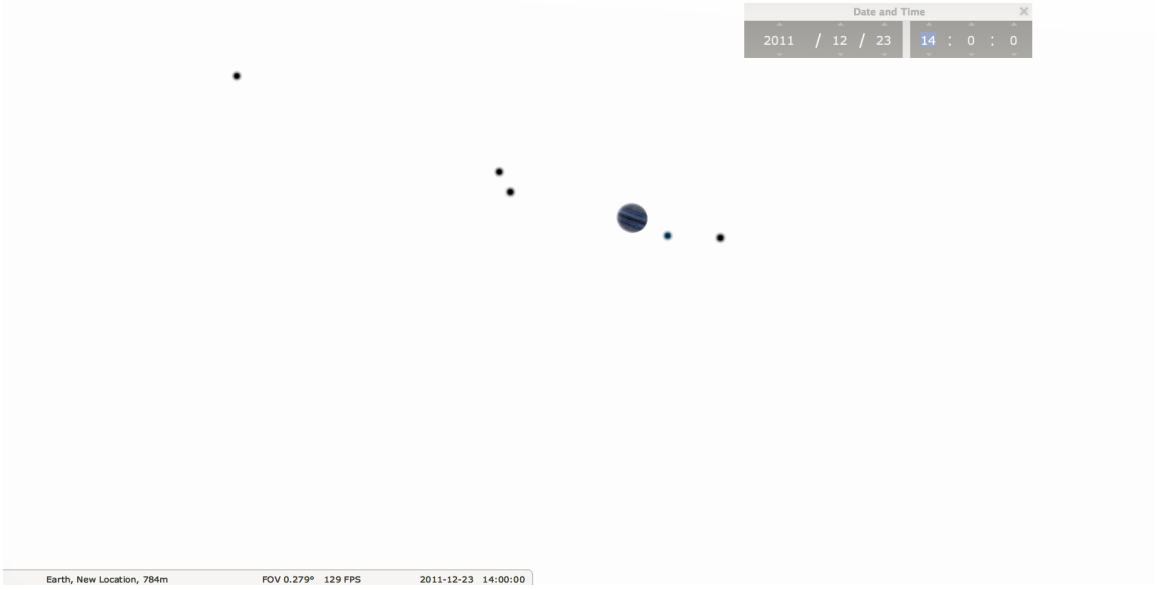
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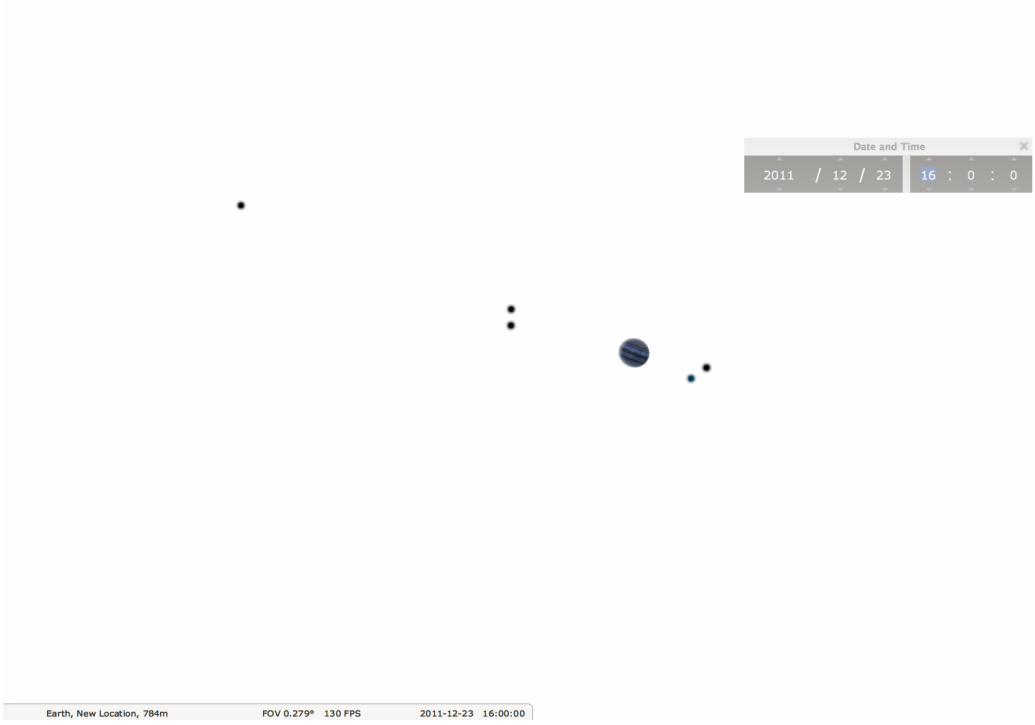
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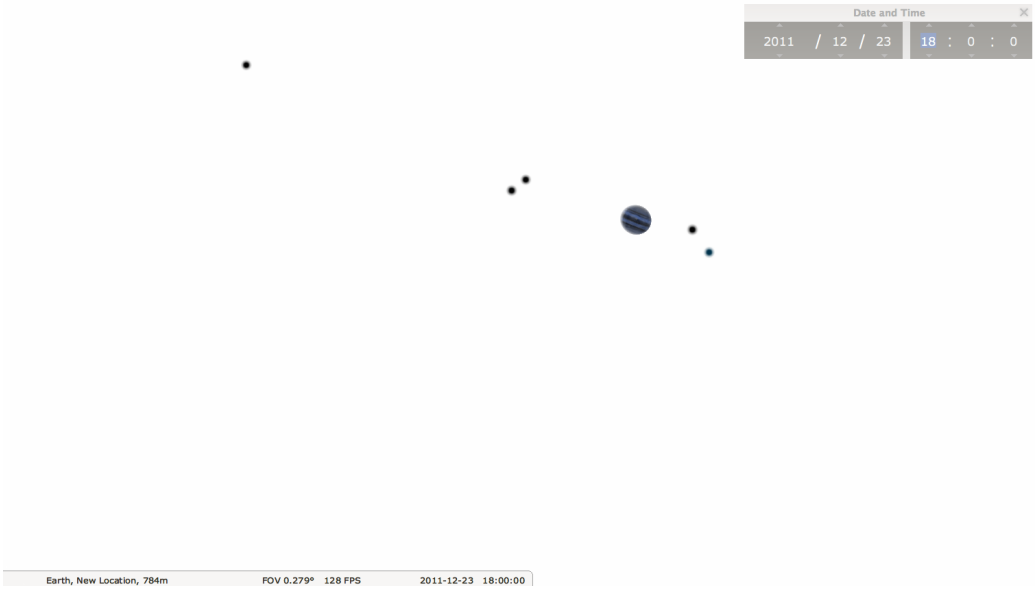
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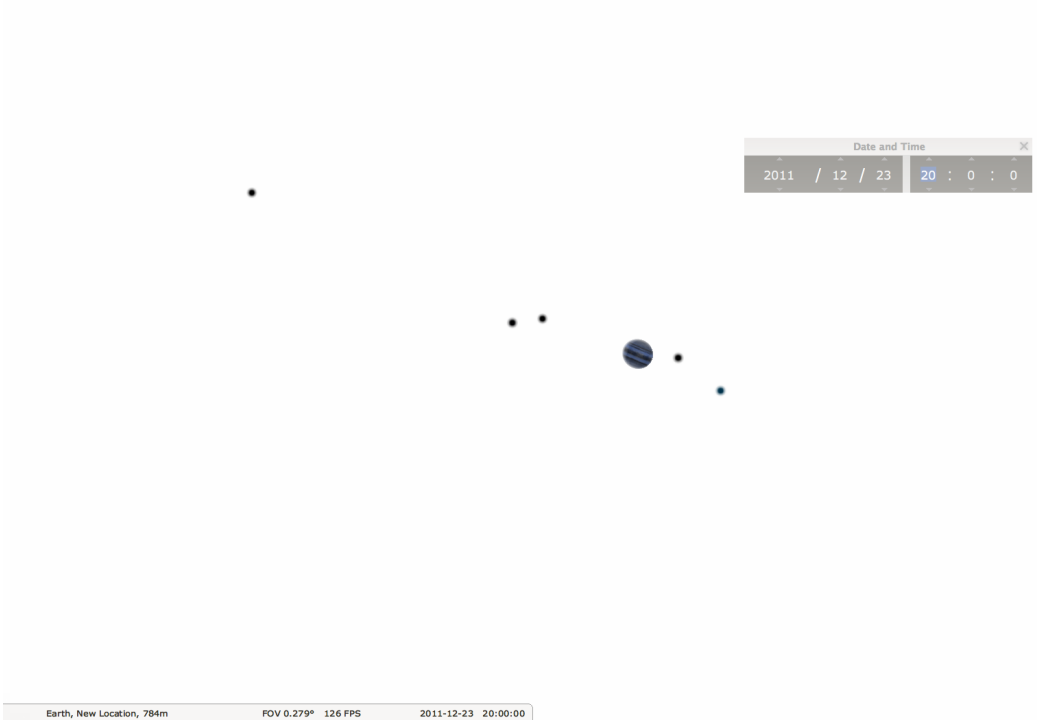
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