ASEN 5050 – Spring 2021

HW 3 Supplement – STK Instructions

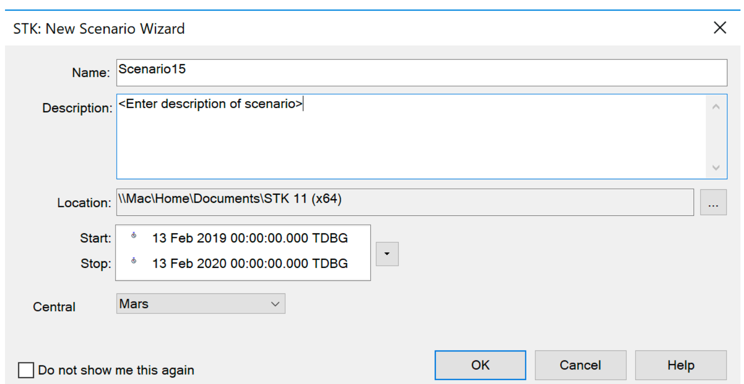
Complete these instructions to answer questions in HW 3

Instructions

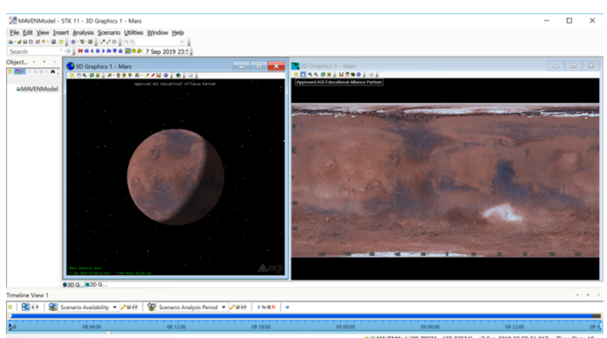
Using STK 11/Astrogator, create a scenario with a satellite orbiting Mars, similar to the MAVEN spacecraft. Follow the outlined procedure and answer the questions in the lab problem statement:

<u>Creating a Baseline Scenario</u>

1. Open STK. In the top menu bar, click "View" and then "Planetary Options".
2. Click "Create Scenario" in the welcome popup.
3. Create a scenario with the name "MAVENModel" using a start time of 13 February, 2019 00:00:00.000 TDBG (we will learn about TDB time soon) and stop time that is 1 year later by entering this information in the New Scenario Wizard screen. Select "Mars" as the central body, then click "OK".



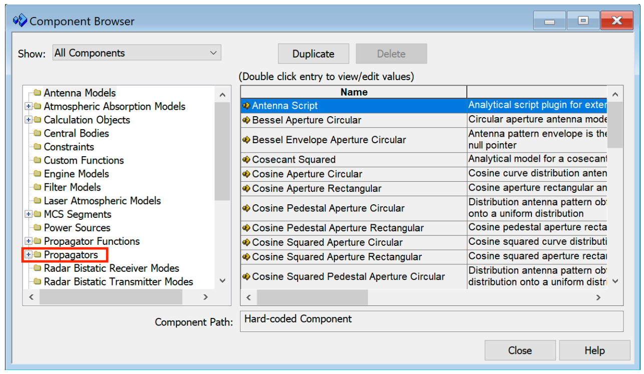
4. The STK window will then update to appear as follows (Be patient if it takes a little while to load):



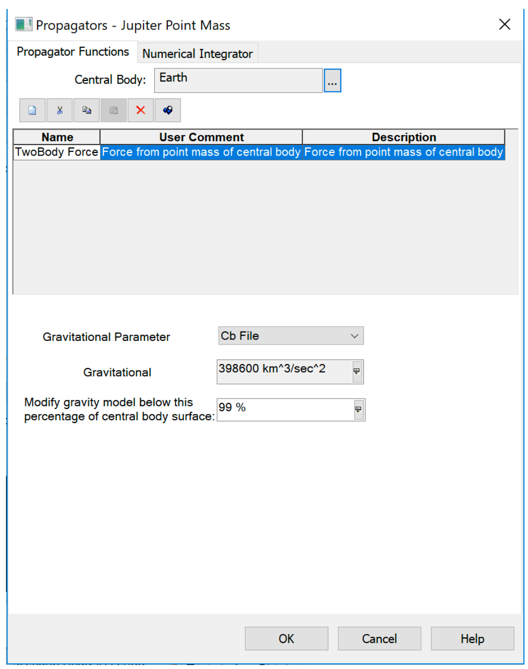
This window features both a 3D graphics window and a 2D ground track view (a projection of the satellite's location on a body's surface), with a panel on the left indicating the objects available within the STK scenario. Be sure to save this scenario by clicking the "Save" button or using the "File"→"Save" options within the menu. **Be sure to press the save button regularly!!!**

Creating Dynamical Models for Propagation

5. First, we will create two dynamical models to govern the motion of a spacecraft near Mars. To define this dynamical model, click "Utilities" in the top menu bar of the STK window and click "Component Browser". You should see a pop-up appear as follows:

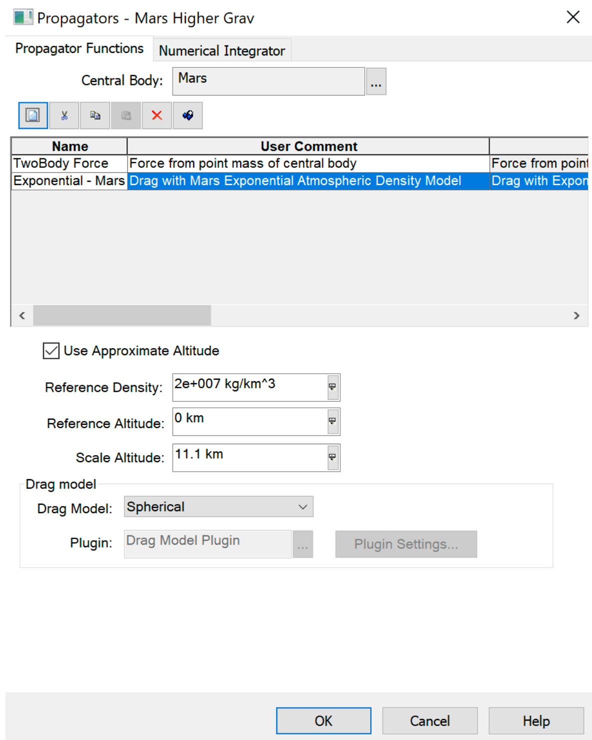


6. On the lefthand panel of the Component Browser, click Propagators, highlighted in red above. Then select "Earth Point Mass" and click the "Duplicate" Button. Name this propagator "Mars Point Mass" and click "OK". Double click the propagator you just created. A window should appear as follows:



7. Change the central body to "Mars" by clicking the "…" button and selecting the body from the list. In the list of forces represented in this dynamical model, there should only be a "TwoBody Force", which models the gravitational environment of Mars as identical to that of a point mass.
8. You should see the gravitational parameter, representing μ, update. Then, click OK.
9. Duplicate the propagator you just created and name it "Mars Drag". Then, double click the new propagator, and in addition to the "TwoBody Force" already in the list, we will add the force due to atmospheric drag. Use the blank page icon above the now empty list to add a new

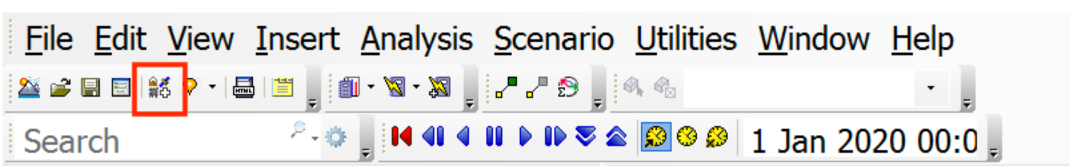
force: “Exponential - Mars” under the “Atmospheric Models” icon. Click OK. The propagator window should then appear as follows. Click to OK to save your changes. You have now created a dynamical model that captures both the point mass gravitational contribution of Mars and the perturbing force due to atmospheric drag.



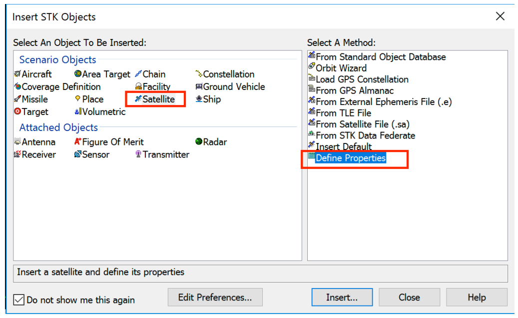
10. Close the component browser.

<u>Create and Configure a Spacecraft</u>

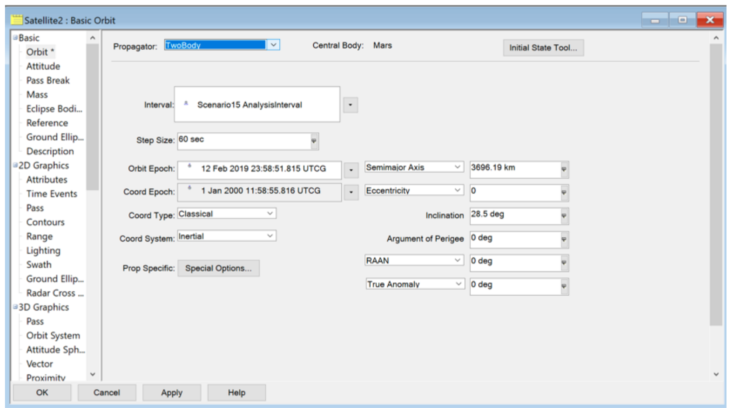
11. Insert a satellite in orbit about Mars either by clicking the button highlighted by a red square in the figure below, located within the toolbar at the top of the window or accessing the “Insert”→”New…” option in the menu bar.



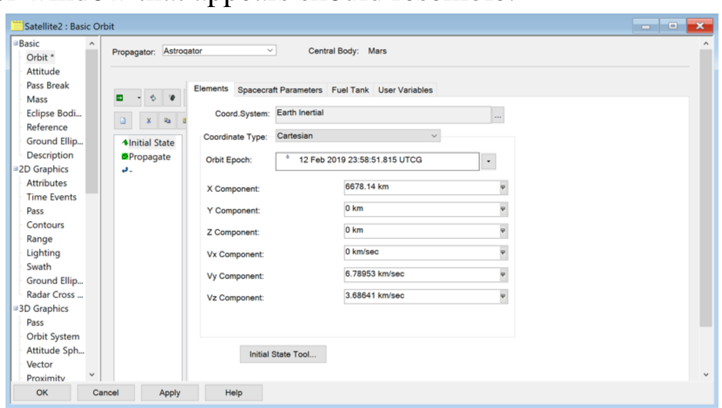
12. An “Insert STK Objects” popup should appear. Select the “Satellite” object on the left panel of this window and click the “Define Properties” method for inserting the object. These options are highlighted in the picture below. Once the desired object and insertion method have been selected, click “Insert…”.



13. The satellite's properties window then appears as displayed below. On the "Basic"→ "Orbit" page of this window, select the "Propagator" dropdown menu and click the "Astrogator" label.



The new Astrogator window that appears should resemble:



Astrogator is a powerful feature of STK that enables the construction of a Mission Control Sequence (MCS). An MCS is essentially a sequence to define the various phases of a mission: initial conditions, propagation over some time interval or until an event is reached, application of maneuvers, etc. When propagating a satellite in Astrogator, we can define various force models, add vectors of interest, perform propagations near a variety of bodies, generate reports describing the satellite state at various locations along the trajectory, and even target transfers. In this lab, we will explore the fundamental features of Astrogator.

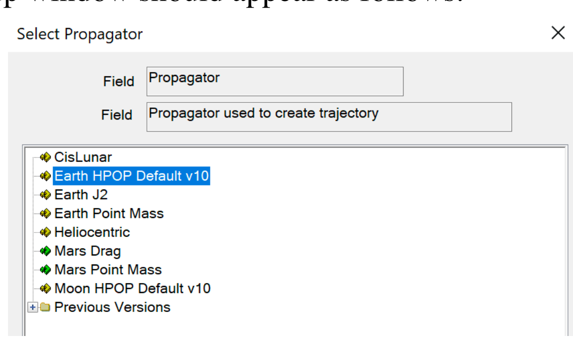
14. Configure the MCS (which appears on the lefthand side of the Astrogator panel). By default, STK adds two components of the MCS: an initial state, and a propagation segment. Keep these two segments.

15. Click on the "Initial State" segment in the MCS. Use the following parameters to define the satellite's orbit in the "Elements" tab in the panel on the righthand side:
    a. *Coord. System: Mars J2000 (After clicking the "…" button next to Coord. System, click Mars as the body on the left panel of the popup window and on the right panel select "J2000". To see the definition of this coordinate system, right click the "J2000" and select Properties.)*
    b. *Coordinate Type: Keplerian*
    c. *Element Type: Osculating*
    d. *Orbit Epoch: 13 February 2019 00:00:00.000 UTCG*
    e. *Eccentricity, e = 0.45454*
    f. *Semimajor axis, a =* 6463.8 km
    g. *Inclination, i =* 74.924°
    h. *Right Ascension Of Ascending Node, Ω = 1.2410°*
    i. *Argument of periapsis, ω =353.31°*
    j. *The initial condition is located at a true anomaly of 199.38 degrees.*

    Once these values have been entered to define the initial state of the spacecraft, click the "Apply" button to save your changes.

Answer questions b and c in HW 3.

16. Rename the satellite to "MAVEN_pm" by right-clicking on the "Satellite1" label on the left panel of the STK window and selecting "Rename".
17. Next, configure the "Propagate" segment by clicking its label in the MCS. A new panel should appear on the righthand side of the Astrogator page. Click the "…" button next to the Propagator selection box. We will change the integration and dynamical model properties via this option. A new popup window should appear as follows:

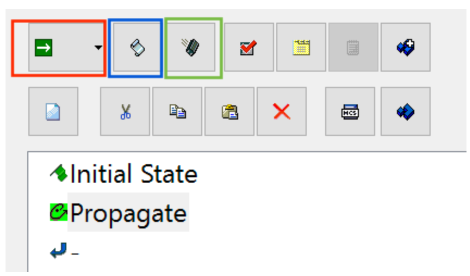


    Select the "Mars Point Mass" propagator you created from the list and then click "Ok". This propagator only includes the point mass model of Mars' gravity, allowing us to integrate the motion of the satellite in the two-body problem. Once you have returned to the "Propagate" configuration panel and the "Propagator" textbox has updated, click "Apply". This panel also enables configuration of the time interval, or other condition, over which the spacecraft is integrated. For this example, let's define the "Propagate" segment to integrate over a given time interval – ten times the orbital period. First, click on the "Duration" line in the "Stopping Conditions" list. Below this list are some textboxes. In the "Trip" box, enter ten times the orbital period you calculated. You may change the units by clicking the ruler icon at the right of the textbox and selecting the desired unit format. In the "Sequence" textbox, ensure that "STOP" appears. This property tells the propagator to stop integrating the motion of the spacecraft after a time interval equivalent to the listed duration. Once you have configured these properties, click the "Apply" button.

18. Change the color of the satellite orbit by double-clicking on the "Propagate" segment in the MCS to reveal an "Edit Segment" popup window. Change the color in the "Color" dropdown menu. Choose a color that will appear clearly on a white background!

Run the MCS

19. Return back to the "Basic"→"Orbit" page. Run the MCS and integrate the motion of the spacecraft for one orbital period by clicking the "Run Entire Mission Control Sequence" button highlighted in red below. To clear the graphics from the 3D graphics window at any time, simply click the "Clear Graphics" button highlighted by the green box below. The summary button highlighted by a blue box below will allow us to generate reports providing information about the satellite's trajectory.



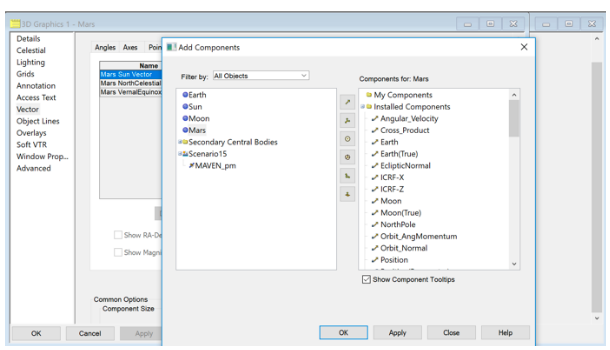
Have you saved recently?

Configure the 3D View

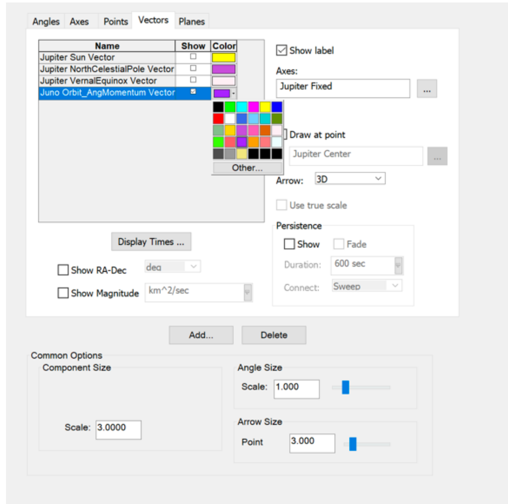
20. Once you have run the MCS, navigate to the 3D graphics window to view the orbit in three dimensions near Mars. You may need to zoom in/out to view the entire orbit – this can be achieved by holding the right click button on your mouse while dragging the mouse towards or away from you. To rotate the view, click the left button on your mouse on a region in the 3D graphics window and drag. To remove the Mars shadow from the 3D graphics window, navigate to the 3D graphics properties window (the yellow page icon at the left of the toolbar in your 3D graphics window) and select the "Lighting" page. Then, uncheck the "Enable Lighting" property. Click "Apply"
21. To change the background color of this picture to white, select the "Details" page in the 3D graphics properties window. Under "Window Background" select the color white. Click "Apply" and then "OK".
22. The line representing the orbit is thin – let's increase the thickness. Navigate back to the satellite properties window (you can double click the satellite in the object panel on the very left in the STK window), and under the "2D graphics"→"Attributes" window, click the "More" next to the second item in the list (with a start date matching the initial epoch). Under "Graphics

Attributes", increase the line width to the maximum thickness using the drop down menu. Click OK to save your changes, then "Apply" in the "2D graphics attributes" window. Run the MCS again and navigate back to the 3D graphics window to view the orbit. (Sometimes you may have to come back to this step and reselect this option)

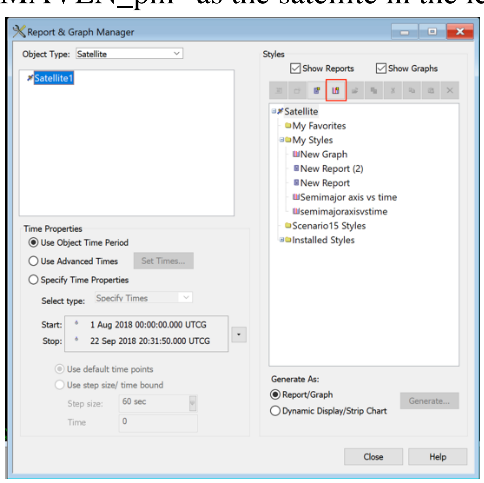
23. Then, select the "3D Graphics"→ "Model" page. In the "Details Threshold" panel, increase the value for all options to the maximum by dragging the blue icons all the way to the right, or entering the value "1e+012 km" in the textboxes. This will allow you to see the spacecraft within its orbit, even when zoomed out in the 3D Graphics window.
24. To view "MAVEN_pm" with a marker that resembles a spacecraft: under "Model", increase the value in the Log scale textbox to around 6.50 or so. The Model file should list "satellite.dae" which will allow us to see a model satellite in the graphics windows. Then click "Apply". You may adjust the Log scale textbox value iteratively.
25. Other information can also be added to the 3D graphics window. For instance, we can add a vector representing the angular momentum of a satellite as it orbits the Earth. In this example, let's add the angular momentum vector for the satellite in the 3D graphics window. To add this vector, navigate back to the 3D view. Then, in the 3D graphics properties window (click the properties button, a yellow page icon at the very left of the toolbar in the 3D view) to the "Vector" page using the list on the leftmost panel.
26. Some sample vectors are already available in the Vector list on this page. However, to add a different vector, click the "Add…" button. Then, a new popup window will appear as shown below:



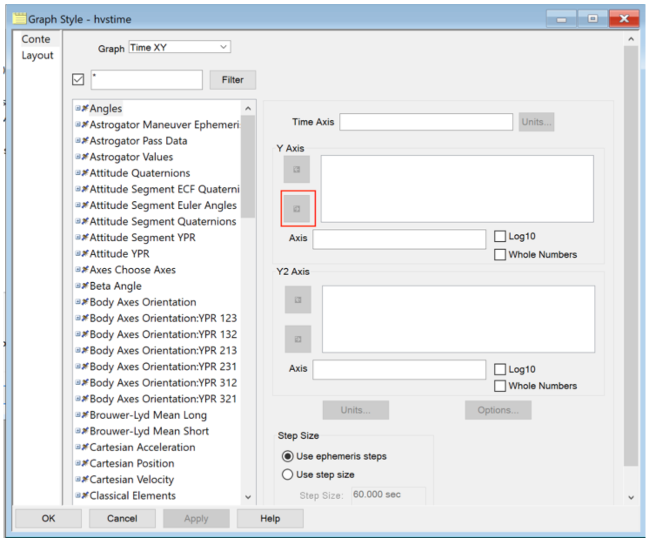
27. Select your spacecraft from the lefthand panel, indicating which object the vector will be computed for, and then "Orbit_AngMomentum" from the right panel. Although there are many options for similar vector, this particular selection computes the orbit angular momentum relative to the central body of the scenario (you can verify this by right-clicking "Orbit_AngMomentum" and clicking the properties option to view the definition of the quantity). Click "Ok" and return to the Vector page of the 3D graphics properties window. Now, "MAVEN_pm OrbitAngMomentum" appears on the vector list, and the checkbox under "Show" should be checked. You can modify the color of this vector by double-clicking the colored square next to the vector label and then clicking the small drop-down arrow that appears. Then, select the color of interest, one that is clear to view with the white background.



28. Retain the rest of the default properties for the vector indicating the satellite's angular momentum, ensuring that the "Show label" box has been checked. You may wish to modify the vector size by changing the value in the "Scale" box within the "Component Size" panel. To view the time evolution of this vector, run the MCS again. Then, return to the 3D graphics window, change the view perspective if necessary by rotating/zooming, reset the scenario time via the red reset button in the animation toolbar. Then, click play and watch the satellite/s, planet/s, and vector/s evolve through the scenario window. You can increase the time step to speed up the animation by using the "Increase Time Step" button within the animation toolbar. Note that we have purposely plotted the specific angular momentum vector using the central body as a basepoint – the reason why is that Mars is fixed in this view, so we can more clearly view the direction of this vector as a function of time. If this vector were attached to the moving spacecraft, it would be difficult to examine the time evolution of the direction of the vector.
29. Follow a similar process to the add the Eccentricity vector for the spacecraft orbit to the 3D graphics window by adding the "Ecc" vector associated with MAVEN_pm.
30. Let's supplement this vector visualization with a graph displaying the magnitude of h and e. To create a graph click the "Analysis" tab in the top menu bar, followed by "Report and Graph Manager". Then, click the "MAVEN_pm" as the satellite in the leftmost panel.



31. Single-click the “New Report” icon which is highlighted in red in the figure above, naming the new report hvstime. Either click away from this report to create it to automatically reveal a popup window or right-click this report once it is created and click “Properties”. Do not double-click it (that would generate an incorrect report)! In the left panel, expand the “Vectors (J2000)” option in the long list, then expand the “Orbit_AngMomentum” and select “Magnitude”. Then, click the right arrow under the “Y-axis” option, highlighted in red below. This will add the quantity to the list of quantities displayed on the vertical axis of the figure.



32. Click “Apply” to save your settings. You will return to the main report and graph manager window. Change the “Time Properties” in the bottom left of the Report & Graph Manager window as appropriate – you can update the start, end times or the time step to influence computation time and fidelity of the data points. Once you have selected an appropriate time period and time step, click the “Generate” button to view your graph.
33. Repeat this process to create a second graph for the eccentricity, using the quantity “Vectors (J2000)”→ “Ecc”→ “Magnitude”.

Have you saved recently?

<u>View the simulation of the spacecraft</u>

34. In the 3D graphics window you can watch the spacecraft move within its orbit by using the animation toolbar at the top of the STK window:

35. The play button runs the animation, the up and down arrows change the time step, and the red reset button return the spacecraft to its original location at the beginning of the scenario.

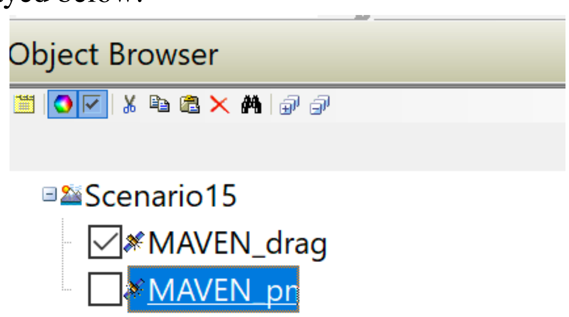
Answer questions d, e, and f in HW 3

<u>Create a Second Spacecraft</u>

36. We will create a second spacecraft to be propagated using the higher fidelity gravitational model. To create this second spacecraft, we will save some time by right-clicking the existing

"MAVEN_pm" spacecraft in the Object Browser within the main window. Click "Copy". Then, right click "MAVEN_pm" and click "Paste".

37. A new spacecraft has been added to the scenario. Right click the new spacecraft to name it "MAVEN_Drag".
38. Deactivate the existing angular momentum and eccentricity vectors for "MAVEN_pm" by navigating to the 3D graphics window and accessing the "Vector page". Uncheck the "Show" box. Use a similar process as earlier to add the orbit angular momentum and eccentricity vectors for the "MAVEN_Drag" spacecraft. (Ensure that you select the correct new spacecraft in the "Add Components" window when adding the vector)
39. Use a similar process as earlier to create graphs of the specific angular momentum and eccentricity magnitudes for the "MAVEN_Drag" spacecraft. (Again, ensure that you select the correct new spacecraft in the left panel of the "Report and Graph Manager" main window)
40. Double click the "MAVEN_Drag" spacecraft to configure it and access its properties window. You should see all of the properties of the "MAVEN_Drag" spacecraft. We will keep the same initial condition, but update the propagation time and propagator.
41. Under the MCS, navigate to the "Propagate" segment. Update the Propagator to the "Mars Drag" dynamical model you created. This will allow us to capture the gravitational contribution due to atmospheric drag near Mars. Ensure the trip value for the duration stopping segment is 10 times the orbit period you computed using the initial conditions.
42. Click "Apply" to save your changes.
43. To remove the orbit of "MAVEN_pm" from the 3D graphics window and only display the trajectory of "MAVEN_Drag", simply uncheck the checkbox next to "MAVEN_pm" in the Object browser as displayed below:



44. Run the MCS for the "MAVEN_Drag" spacecraft. Return to the 3D graphics window. You may need to rotate/zoom to view the orbit. Play the animation of the spacecraft orbiting Mars and note the spacecraft motion as well as the time evolution of the two vectors.

Answer questions g, h, i, j in HW 3