Set Properties

First, set the epoch for the satellite propagation. Right click the scenario, select Properties Browser and then Time Period under the Basic option. Change the Period Start to 1 Jul 2005 00:00:00.00. Change the Period Stop to 2 Jul 2005 00:00:00.00. Change the Epoch to agree with the start time.

Click on the 2-D map and then the properties icon. Click the Details tab. Deselect all the Items, and turn the lat/long lines off. Look at what this does to your map display.

Propagate using J2 Perturbation

Create a satellite in the browser window called 'J2' that has the following properties:

- $a = 7000 \text{ km}$
- $\Omega = 10 \text{ deg}$
- $\omega = 20 \text{ deg}$
- $i = 45 \text{ deg}$
- $\nu = 90 \text{ deg}$
- $e = 0.05$
- $\omega = 20 \text{ deg}$
- step size = 60 sec

Select J2Perturbation from the propagator menu. Select OK to begin the propagation.

1. Use this space to calculate $d\omega/dt$ and $d\Omega/dt$ (in deg/day) for linear perturbations from Earth J2-oblateness:

2. Right click on the satellite, and select Tools -> Graph -> Classical Orbit Elements -> Create. You may need to change the orbital elements to the desired ones. What is the actual change over one day for:

   a) $\omega$
   b) $\Omega$

Note: This can be accomplished by creating a report and reading off the values. Right click on the satellite, Satellite Tools->Report->Classical Orbit Elements->Create.
Re-propagate the satellite with the Two Body Propagator and look at the resulting graph for the orbital elements to see how the elements are changed.

3. How does the argument of perigee behave and what does this mean?

4. Try a few inclinations from 60-65 degrees with the J2 propagator. What is the inclination at which the satellite argument of perigee does not experience any J2 effects? How would you compute this inclination using the equation for $d\omega/dt$ from step 1.

**Sun Synchronous Satellite**

5. Change the scenario Stop Time to 11 Jul 2001 00:00:00.00 so that the satellite will propagate for a full 10 days with the J2 propagator. Create a graph and a report of the Beta Angle. (Beta Angle is the angle between the satellite-sun vector and the orbital plane.) What is the initial and final beta angle? What is the average rate of change (per day) in beta angle?

6. Use this space to calculate the inclination needed for a sun synchronous satellite (due to J2 perturbation) with a semi-major axis of 7000 km and an eccentricity of 0.001:

7. Change the properties of your satellite so that it has this inclination and eccentricity, and again propagate the satellite for 10 days. Graph (or use Report) the beta angle. What is the initial and final beta angle? What is the average rate of change (per day) in beta angle? How does this compare to the rate computed in step 5? (Note: you won’t be able to completely reduce the beta angle rate to zero due to the elliptical orbit of Earth around the sun, and the tilt of Earth’s equatorial plane with respect to its orbital plane. However, the beta angle rate of a sun synchronous satellite will be much smaller than that of a non sun synchronous satellite at a similar altitude).

8. Use this space to recalculate the inclination for the same elements if you wanted a sun synchronous orbit around Mars instead of Earth. You can get the necessary constants for Mars (i.e. J2, radius, $\mu$, etc.) from STK. Click on View, Astrogator Browser, Central Bodies, double-click Mars. Under Gravity Models – Analytic, click Details.
Propagate with Atmospheric Drag/Solar Radiation Pressure/Gravity Model

Create a new satellite in the browser, and call it 'Radiation.' Set the orbital altitude (perigee and apogee) to 300 km, with an inclination of 28.5 degrees (all other orbital elements zero). Set the orbit epoch to 1 Jul 2005 00:00:00.00 and the stop time to 6 Jul 2005 00:00:00.00 (five full days). Using the High Precision Orbit Propagator (HPOP), under the Force Model button, change the area to mass ratio for both the solar radiation model and atmospheric drag model to 0.03 m²/kg. Change the coefficient of drag to 2.0 and the coefficient of reflectivity to 1.0. Then right-click on the satellite, selecting Report - Classical Orbit Elements - Create to get information on the orbit. Also view the graph of the semi-major axis.

8. How much does the semi-major axis change in 5 days? _______________

Change the Maximum and Maximum Order of the gravity model to 0 and re-propagate the orbit. This removes the gravity model from the calculations. Graph the semi-major axis.

9. What effect does the gravity model have on short scale semi-major axis changes?

Simulating Mars Pathfinder

Define a new scenario with two planets, Mars and Earth, and a satellite called 'Pathfinder.' Under Basic Properties for each planet, set the ephemeris source to DE 405 Mars and DE 405 Earth, respectively. For the satellite, under 2D Graphics Properties - Pass, set Orbit Track Lead Type to All. Set the Epoch and Start Times in scenario Basic Properties to 1 Mar 1997 00:00:00.00, and the Stop Time to 1 Mar 1998 00:00:00.00. Set the Time Step to 3600 sec (1 hr) under scenario Basic Properties, Animation. Set the following settings under the Scenario 2D Graphics Properties:

- General: Show Labels - OFF
- Vehicles: Show Orbits - ON, Show Orbit Markers - ON, Others - OFF
- Planets: Show Orbits - ON, Show Inertial Positions - ON, Others - OFF

Now change the map so it's heliocentric. Click the Map Central Body button and select the Sun. Click on the 2-D map and click the properties icon. Select Orthographic as the projection type, and CBI (central body inertial) as the Displayed Coordinate Frame. Make the Display Height 600 000 000 km and the Center - Lat to 84.6 deg (not quite polar). Animate the scenario to watch Earth and Mars orbit the Sun.

To create another map, this one Mars-centered, click View, Duplicate 2-D Graphics Window – Sun. Follow the process above to change the central body to Mars, turn off
the lat/lon lines, and make the projection Orthographic and CBI, choosing an appropriate Display Height (40 000 km is good). Set Center - Lat to whatever you prefer.

Normally in interplanetary modeling, you would define the initial state as an Earth orbit, such as GEO. But in this example, we're going to start the probe at mid-mission. Use the following information for the initial state in your Mission Control Sequence (remember, this is available when you use Astrogator as your propagator):

- Coordinate System - Sun Centered Mean J2000 (Under Central Body Inertial folder for coord. syst.)
- Element Type - Keplerian
- Orbit Epoch - 1 Mar 1997 00:00:00.00
- \( a = 193216365.381 \text{ km} \) \( \Omega = 0.258 \text{ deg} \)
- \( e = 0.236386 \) \( \omega = 71.347 \text{ deg} \)
- \( i = 23.455 \text{ deg} \) \( \nu = 85.152 \text{ deg} \)

Now change the Propagate sequence, making the propagator Heliocentric. Click the Advanced button and turn OFF the Use option for Maximum Time Propagation. Make Periapsis the Stopping Condition, and in the Central Body field, substitute Sun for Earth. Run the sequence.

9. On what day was the probe's closest approach to Mars? _______________

To stop near Mars instead of swinging right by it, return to the Propagate segment and, in the Central Body field, substitute Mars for the Sun. Set the Coordinate System under Segment Properties to Mars Central Inertial. Run the scenario again. Use the result button and the summary icon to obtain the distance from Mars.

10. What is the distance to Mars at the end of the transfer? _______________