

## ASEN5050 – STK Lab #2

**Due:** Friday 10/30/15 at 9:00 am

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The purpose of this lab is to exercise STK's ability to map orbits and create orbit transfers. We'll build a few simple orbit transfers, and then invoke STK's targeter. This uses the module "Astrogator".

### **Map Projections**

Start up STK. Either at the Welcome Screen, or in the **File** menu, click **New** and create a **New Scenario**. Use the default time period. Save this in its own directory (save frequently!!).

Insert a **New Satellite** using the "Define Properties" method (not the Orbit Wizard!). Give the satellite a semi-major axis of 7000 km, an inclination of 40 degrees, and set all the other orbital elements equal to zero. Hit OK.

Animate the satellite and watch the satellite go along its groundtrack. With the 2D graphics window selected, click on the **Properties** icon (in the top row of the window's icons) and select the **Projection** tab. Try different map projection types.

1. How does the appearance of the groundtrack change compared to the equidistant cylindrical projection for:
  - a) Mercator projection:  
The polar regions are much bigger, equatorial region is more squashed.
  - b) Mollweide projection:  
The map isn't rectangular, and the longitude lines are curved.
  - c) Orthographic projection:  
It's a true projection of the sphere onto a plane perpendicular to the line of sight.
2. In the orthographic projection, what is the *minimum* display height (round to the nearest thousand kilometers) that allows you to see the whole visible hemisphere of the Earth? 13000 km
3. Set the projection to Azimuthal Equidistant with a Center Lat of 90 deg and a Center Lon of 0 deg. What is the range of latitudes visible in this perspective? -90 to +90 degrees

Set the projection back to Orthographic. Change the projection Center Latitude to **90 degrees**, the display coordinate frame to **ECI** and the Display Height to **100,000 km**. Click the box to Show Orthographic Grid and click **OK**. Double-click the satellite again and click the **2D Graphics / Pass** tab, and change the *Orbit Track* Lead Type to All (not *Ground Track* but *Orbit Track*). Click **OK**. We will use this window next.

### Create a Hohmann Transfer Orbit

Use:  $R_e = 6378.14 \text{ km}$   
 $\mu_e = 398600.44 \text{ km}^3/\text{s}^2$   
 1 sidereal day =  $23^{\text{h}} 56^{\text{m}} 4^{\text{s}}$

Name the satellite you have created 'Hohmann' by left clicking once on 'Satellite1' in the browser window. Double-click on Hohmann; under the **Basic** properties menu, select the **Orbit** tab and then select "Astrogator" as your propagator. This will open the **Mission Control Sequence (MCS)** window.

There should be two segments of your control sequence already in the window to the left: Initial State and Propagate. Right-click on the Initial State, and change its name to Inner Orbit. In the right-hand window, change the coordinate type to Keplerian and change the orbit properties so that the orbit is a circular orbit with an altitude of 250 km and an inclination of zero.

Still in the Astrogator MCS, with the Inner Orbit highlighted, find and explore the "Spacecraft Parameters" and "Fuel Tank" tabs. Set the fuel mass to 5000 kg and the dry mass to 500 kg (make sure to change the maximum fuel mass, too).

4. Use this space to calculate the period (in seconds) of this initial orbit by hand:

$$P = 2\pi \sqrt{(6378+250)^3 / 3.986e5} = 5370.1 \text{ seconds}$$

(check your work using STK!)

Select the Propagate segment. Choose Earth Point Mass as your propagator in the window to the right. Select a Trip time that allows your satellite to complete exactly one period.

Now insert a segment into your MCS list by right-clicking once on the propagate segment and selecting "Insert After...". Select Maneuver from the menu, and name the segment 'DeltaV1'. Make this segment an Impulsive maneuver type. With DeltaV1 highlighted, set the following values in the windows (two tabs) to the right:

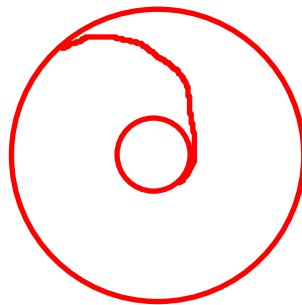
Attitude control:	Thrust vector
Thrust Axes:	VNC(Earth)
Vector Type:	Spherical
Azimuth:	0 deg
Elevation:	0 deg
Magnitude:	2.44008316 km/s for deltaV1.
Update Mass Based on Fuel Usage:	ON

Now insert another Propagate segment and call it Transfer Ellipse. Change the color so that it will be different from the Inner Orbit, which may be done by double-clicking the segment or selecting “Properties...” from the right-click menu. Select Earth Point Mass as the propagator. Set the Stopping Condition to Apoapsis by inserting a new stopping condition and removing the pre-existing stopping condition. Be sure to check that the “Duration” stopping condition is no longer active!

Insert another “Impulsive” Maneuver segment named 'DeltaV2'. Set the same conditions as for the previous Delta V, but use a magnitude of 1.47203386 km/s for deltaV2. Insert a final Propagate segment and call it 'Outer Orbit.' Again, change the color to distinguish it from the previous segments, select Earth Point Mass as the propagator, and set the Trip time to 24 hours (86,400 sec).

Save.

Now you can run the Astrogator. Click the green arrow button on the toolbar. The Astrogator will calculate for a moment and then the orbit will appear on the map. Draw the 2-D results in the space below:



Produce a report containing the MCS Summary from the toolbar to answer the following questions (First click on the segment of interest and then click on the Summary icon in the toolbar):

4. How much fuel does each impulsive maneuver consume (approx. 5 decimal points)?

a) Fuel for DeltaV1: 3100.28349 kg

b) Fuel for DeltaV2: 944.72753 kg

5. How does this change if you reduce the dry mass of the spacecraft to 50 kg without changing the fuel mass? Rerun the sequence with the new dry mass.

a) Fuel for DeltaV1: 2846.62387 kg

b) Fuel for DeltaV2: 867.43164

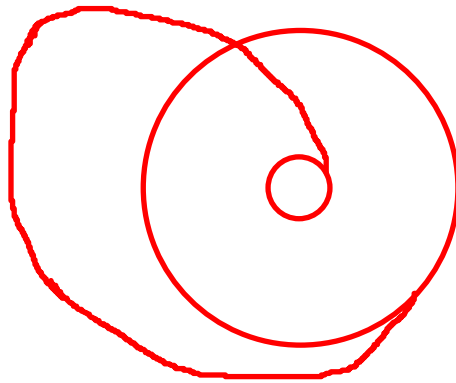
### ***Creating a Bielliptic Transfer Orbit***

Insert a **new satellite** in the browser using the “Define Properties” method, and call it 'Bielliptic.' Under the **satellite Properties** menu, go to **2D Graphics, Pass, Orbit Track**, and change the **Lead Type** to “All”. Back in the **Basic/Orbit** menu, select

Astrogator as your propagator. You should now understand enough about Astrogator to be able to enter in the following  $\Delta V$ s to create a bielliptic transfer orbit. There should be four Propagate segments and three “Impulsive” Maneuver segments. Use the same initial state as was used for the Hohmann transfer. Make sure to “Update Mass Based on Fuel Usage”.

$\Delta V_1$ : 2.8050121 km/s (Propagate end condition: apoapsis)  
 $\Delta V_2$ : 0.9451596 km/s (Propagate end condition: periapsis)  
 $\Delta V_3$ : -0.4756517 km/s (Propagate for 86400 sec)

Make sure the 2D projection is on an orthographic projection (ECI) with a center latitude of  $90^\circ$  and a 200,000 km display height. Remember to change to Earth Point Mass for propagators and all the other parameters to be changed for each step. Draw a picture of the result in the space below.



6. For a satellite with 500 kg dry mass and 5000 kg fuel mass, how much fuel is used in this maneuver?

- a) Fuel for  $\Delta V_1$ : 3380.22634 kg
- b) Fuel for  $\Delta V_2$ : 582.44779 kg
- c) Fuel for  $\Delta V_3$ : 229.49770 kg

Is 5000 kg of fuel sufficient for this maneuver? Yes.

Save.

### ***Using Targeting in STK***

We'll now let STK calculate the  $\Delta V$  for the Hohmann transfer we performed earlier.

Create a **new satellite** in the browser as usual, and call it 'HohmannTarget.' Again, from the **satellite Basic Properties** menu, choose Astrogator as the propagator. Give the satellite the same initial orbit as you did before, and propagate it. But instead of adding an Impulsive Maneuver as your next segment, insert a Target Sequence segment, and call it 'Start Transfer.' Nest an Impulsive Maneuver in the Target Sequence, and call that maneuver 'DeltaV1.'

With DeltaV1 selected, look in the right-hand window, select Thrust Vector as Attitude Control, Cartesian as the Vector Type, and VNC(Earth) as the Thrust Axes. Next, set the X (velocity) component as the only control variable by clicking the target icon next to the X component. With the maneuver still highlighted, select the “Results...” button (at the bottom of the screen). Open the Keplerian Elements folder and add Radius of Apoapse as the constraint variable (make sure to click the blue arrow pointing right to add your selection). Click **OK** to close Results.

With the Target Sequence “Start Transfer” highlighted, do the following:

- Look in the window on the right, find the word “Profiles” and directly beneath it is a “Properties” button. Click that.
  - In the “Control Parameters” area, activate the checkbox labeled as ‘use’ for the only control parameter listed. Set the Maximum Step to 0.3 km/sec.
  - In the “Equality Constraints” area, activate that constraint’s “use” checkbox. Two cells to the right of the Use Box you’ll find a “Desired Value” box. Double-click in that field and set the **desired** radius of apoapsis to 42164.14004 km and Tolerance to 0.1 km.
  - Up at the top, find the **Convergence** tab; set the Maximum Iterations to 50, and close the window.
- Make sure the targeter is turned on! Toward the top, you’ll find a field called “Action:”. Change this to **Run active profiles**. Change the **When Profiles Converge** field to **Run to RETURN and continue**.

Save.

Now insert a Propagate segment nested under the Targeting Sequence with the name 'Transfer Ellipse', using the same values as you did for the 'Hohmann' satellite 2<sup>nd</sup> propagate segment.

Insert another Target Sequence segment named 'Finish Transfer.' Nest an Impulsive Maneuver in the Target Sequence (call it DeltaV2). Use the same properties as before, only this time, make Eccentricity the constraint element (while within maneuver). Highlight the Target Sequence segment, and select the properties button. Activate the checkbox labeled as ‘use’ for both the control parameter and equality constraint variables. Set the Maximum Step to 0.3 km/sec. Leave the desired value for Eccentricity at its default value of zero, enter a tolerance for the eccentricity of 0.0001, and close the window. With the Target Sequence still highlighted, make sure the targeter is turned on by selecting **Run active profiles** in the **Action** field. Change the **When Profiles Converge** field to **Run to RETURN and continue**.

Insert one last Propagate segment, called 'Outer Orbit', nested under the Finish Transfer Target Sequence. Set the Trip time to at least 24 hours (86,400 seconds). Now run the MCS and watch the targeting process in the Popup window. (Make sure the “Update Mass Based on Fuel Usage is turned on for all maneuvers).

To see the results of the Astrogator's calculations, select the Target Sequence of interest and examine the summary and/or pop-up window. Find the Magnitude of the DeltaV the Astrogator calculated.

7. How do the DeltaV values calculated by STK for this Hohmann transfer compare with the values you used in Part 2 of this lab (500kg dry mass case)?

- a) DeltaV1(STK): 2.44012358 km/s
- b) DeltaV1(Part 2: Hohmann): 2.44008316 km/s
- c) DeltaV2(STK): 1.47205145 km/s
- d) DeltaV2(Part 2: Hohmann): 1.47203386 km/s