ASEN 6008 – Interplanetary Mission Design
Laboratory 1 – Part 1
Due January 28, 2016

Purpose

This lab is designed to familiarize you with STK. In this lab, you will create satellites, planets, and facilities. You will define their basic and graphic properties. You will learn to use STK's access feature to determine how much time one object can be seen by another object. Finally, you will learn how to create reports, graphs, and dynamic displays using STK. This lab has been designed to be very similar to STK's basic tutorial.

Creating a Scenario

At the *Welcome to STK!* window, click on *Create a New Scenario*. Alternative, if you close the Welcome window, you may create a file by going to Flie → New. Under the New Scenario Wizard, name the scenario "Intro1." Change the Location of the folder to have the name Intro1. Note: In STK, is it VERY helpful to only have ONE scenario saved in a single folder. It is also helpful to save the scenario in a folder with the same name as the scenario (i.e. C:\Documents\username\STK\Intro1). This will prevent overwriting issues. Click Ok. Close the "Insert STK Objects" window that pops up.

Open the Properties Browser: Double Click or Right click on the scenario and go to Properties, or click on the Properties button  . Under *Basic/Time*, set the Start Time, Stop Time and Epoch to:

Start	1 Jan 2000 00:00:00.00 UTCG
Stop	2 Jan 2000 00:00:00.00 UTCG
Epoch	1 Jan 2000 00:00:00.00 UTCG

The Epoch can be selected as AnalysisStartTime

Under *Basic/Animation*, set Start Time to 1 Jan 2000 00:00:00.00 UTCG (AnalsysisStartTime), check the Use Analysis Start Time box and set the Step Size to 60 sec.

Under *Basic/Units*, double-check the following options:

Distance Unit	Kilometers (km)
Time Unit	Seconds (sec)
Date Format	Gregorian UTC (UTCG)
Angle Unit	Degrees (deg)
Mass Unit	Kilograms (kg)

Feel free to explore the other options and when finished click OK.

Make the 2-D window active and open its Properties. On the *Lighting* page, select Show *Subsolar Point*, and select *Show Outline* for both *Penumbra* and *Umbra*. Change Penumbra and Umbra outline colors if desired and click *OK*.

Save the Scenario! (Save early, save often!)

Defining Satellites

We will now create two satellites and work with their graphic properties. First, we'll create a satellite orbit by entering its basic properties. Then we'll use the *Orbit Wizard* to propagate a satellite orbit and take a look at some different Graphics Properties available to the user in STK. We'll look at different line styles, visible sides of the orbit, ground track lead types, lighting styles and swath options.

From the *Insert* Menu, click *New* and select the Satellite icon from the *Scenario Objects*. In the *Select a Method*, Select *Insert Default.* Click *Insert*. Rename the satellite 'LEO' (Right click → Rename).

Go to the LEO satellite *Properties Browser* and go to the *Basic/Orbit* page.

Enter the following values into the *Orbit* page.

Note: You may need to change the Coordinate Type to Classical. To select the Start/Stop time, click the down arrow to the right of the Interval box and pick Select Date for Start Time.

Click the down-pointing arrow to the right of the Semimajor Axis field to change the parameter type for the first Keplerian element to Apogee Altitude. Similarly, change RAAN to Lon. Ascn. Node (longitude of ascending node).

Field	Value
Propagator	J4 Perturbation
Start Time	1 Jan 2000 00:00:00.00
Stop Time	2 Jan 2000 00:00:00.00
Step Size	60 sec
Apogee Altitude	600 km
Perigee Altitude	600 km
Inclination	75 deg
Argument of Perigee	0.0 deg
Lon. Ascn. Node	10 deg
True Anomaly	0 deg

Hit Apply and OK.

Highlight the “Intro1” scenario in the *Object Browser*, from the *Insert* Menu, click *New* and select the Satellite icon from the *Object Catalog*. Under *Select a Method*, highlight Orbit Wizard and click Insert.

Under Type, select *Repeating Ground Trace*. Under Position, check *Approximate Revs Per Day* and set the value to 4. Under Definition, set the *Inclination* to be 45 degrees, the *Number of Revs to Repeat* to 4, and *Longitude of the First Ascending Node* to 5 deg.

For Interval, select *Use Scenario Interval*. Hit Apply then Ok.

Rename the new satellite ‘MEO.’

Click the Animate Forward  button to animate the scenario. Switch to the 2-D and 3-D windows to view the animation.

When you finish, click the Reset  button

Satellite Pass

You can control the appearance of the satellite's ground track and orbit path.

1. Open the *Properties Browser* for the LEO satellite.
2. Go to the *2D Graphics/Pass* page and enable *Show Pass Labels*.
3. Click *Apply* to see your changes in the 2-D Map Window. Each groundtrack now has the associated pass shown.
4. Change *Visible Sides* to *Ascending* and click *Apply*. Click the Animate Forward button to see the changes.
5. Now change *Visible Sides* back to *Both* and change the *Leading/Trailing, Ground Track, Lead Type* to *Half*. When you finish, click *Apply*.
6. Animate the scenario to see the effect of the change.
7. Reset the *Leading/Trailing, Ground Track, Lead Type* to *All* and disable the *Show Pass Labels*. Click *OK*.

Satellite Lighting

You can display lighting conditions for individual satellites in the 2-D window.

1. Open the *Properties Browser* for the MEO satellite.

2. On the *2D Graphics/Lighting* page, turn on the *Sunlight*, *Penumbra*, and *Umbra* options and set other options as follows:

Line/Marker Style	Color	Line Width
Sunlight	Blue	3rd down
Penumbra	White	3rd down
Umbra	Red	3rd down

3. Apply changes and observe 2-D Map window. Magnify  the ground track at the transition point to see the Penumbra. Zoom out  to full view.

4. Back on the *2D Graphics/*Lighting page, Enable *Show Sunlight/Penumbra Boundary at Vehicle Altitude* and click *Apply*. Reset and then animate the scenario.

5. Remove all *Lighting* options and click *OK* to dismiss the page.

Satellite Swath

The satellite swath displays field-of-view areas for a selected ground elevation angle or for a half angle relative to nadir or a surface distance. Swaths can be viewed with either the Edge Limits of the field-of-view shown, or the whole viewable area shaded. In this section, we will see both.

1. Open the *Properties Browser* for the MEO satellite.

2. Go to the *2D Graphics/Swath* page for the MEO satellite and set the *Ground Elevation* to 60 deg. Select *Edge Limits* and click *Apply* to view changes in the Map window.

3. Now, select *Filled Limits* and click *Apply*. Notice the changes in the 2-D window. You can now see the entire field-of-view area represented by the shaded area.

4. Change *Ground Elevation* angle to 80 deg and *Apply*.

Return the *Swath* page to its original state (No Graphics) and click *OK*.

Working with Facilities

Facilities are objects that are defined as stationary locations on the Earth's surface. They are flexible in function, since they can be used to represent ground stations, launch sites, tracking stations, or other structures providing satellite support.

We will create three facilities representing the Deep Space Network (DSN): one in Goldstone, California, the second in Madrid, Spain, and the third in Canberra, Australia.

1. Highlight the “Intro1” scenario in the *Object Browser* window. Click on the *Insert* menu, select *New...*, select *Facility*, under Select a Method, highlight *Insert Default* and click *Insert*. Rename the facility DSN_Cal.

2. From the *Properties Browser* for DSN_Cal, open the *Basic/Position* page. Enter the facility's exact position as follows:

Option	Description
Type	Geodetic
Latitude	35.2 deg
Longitude	-116.9 deg
Altitude	0.000 km

3. Click *OK*.

4. Create a second and third facility using the same means with the information below. Alternatively, you can right click the existing facility then select Copy, Paste and create a duplicate facility, then change the parameters listed below. You may want to change the colors to the right of each facility name (in the Object Browser) so they are unique.

Option	Description
Name	DSN_Spa
Type	Geodetic
Latitude	40.2 deg
Longitude	-4.2 deg
Altitude	0.000 km

Option	Description
Name	DSN_Aus
Type	Geodetic
Latitude	-35.2 deg
Longitude	149.0 deg
Altitude	0.000 km

Determine Access & Apply Constraints

By determining accesses, you can find out when one object can see another object. In addition, you can impose constraints on accesses between objects to define what circumstances allow access. These constraints are defined as properties of the objects between which accesses are being calculated.

1. Highlight the DSN_Cal facility in the *Object Browser* window. From the *Analysis* Menu, select *Access*.

2. Select the LEO satellite and click the *Access...* button in the *Reports* section. This will generate both the Access and the Report. Notice the groundtrack changes in the Map window, they are highlighted where the two objects have access.

Quiz: How many seconds in duration is the total access period between the satellite and the facility?

3. Minimize the Access report for later use.

4. With DSN_Cal still highlighted in the Object Browser window, from the *Properties Browser* select the *Constraints/Basic* page. Enable the *Elevation Angle/Min* and set to 10 deg.

5. Click *Apply*. Notice how the Access graphics change in the Map window.

Note: Constraints limit the time when two objects are "in-view" of each other using different conditions. In this example, the LEO satellite can only be viewed from the DSN_Cal facility when it is at least 10 degrees above the horizon.

6. Resize the report. In the Report window, select *Refresh* from the *Report* menu and notice the change in access duration.

Quiz: What is the total access period now?

7. In the *Constraint/Basic* page, turn off the *Elevation Angle/Min* constraint and Click OK.

8. Close the report and click the *Remove All Accesses* button in the Access window. Close the Access window.

Answer 1: The total access is approximately 2885 seconds. I got 3071 seconds

Answer 2: The new duration due to the constraint is approximately 1601 seconds. I got 1519 seconds

Adding a Planet

The inclusion of planets and stars are often necessary to provide a complete analysis of sensor in-view opportunities. In STK, planets represent objects in heliocentric orbit (as well as the Earth's Moon and the Sun itself). Stars are used to represent "stationary" celestial objects.

1. Highlight the “Intro1” scenario in the *Object Browser* window. Click on the *Insert, Default Object* menu, select *Planet,* and click *Insert*.

2. Open the *Properties Browser* window for the new planet. On the *Basic/Definition* page, select *Moon* as the *Central Body*, and select *DE421* as the *Ephemeris Source*.

3. Click *OK* to apply the changes and close the window. Notice the planet is automatically renamed to Moon.

Reset the animation, and then animate the scenario. Notice the Moon's subplanet point is displayed. This is the location on the Earth that the Moon is directly above. The subplanet label can be removed by going to the Properties Browser for the moon. Under *2D Graphics, Attributes*, uncheck the box *Inherit from Scenario* and uncheck the *Show Subplanet Label* and *Show Subplanet Point*

Adding Sensors to the Scenario

Sensors can be used to represent such equipment as optical or radar sensors, receiving or transmitting antennas, or lasers. They can also be used to define another object's field of view. Although sensors are objects, they are subordinate to, or sub-objects of, the parent object to which they are attached.

1. Go to the *Insert* Menu, select *New*. In the window that pops up, choose *Sensor* (near the bottom). Click *Insert*, then select the LEO satellite in the pop-up window. Close the pop-up windows. (There's also an easy way to do this all with an icon – see if you can find it!) Rename the sensor 'image.'

2. Right click the image sensor, select *Properties*, go to the *Basic/Definition* page, and set the values as follows:

Option	Description
Sensor Type	Simple Conic
Cone Angle	80.00

3. When you finish, click *OK*.

4. Create another sensor for the LEO satellite, and rename it 'track.' Open the *Properties* page for the sensor, and on the *Basic/Definition* page, define the *Sensor Type* as *Simple Conic* with a *Cone Angle* of 35 deg.

5. On the *Basic/Pointing* page for the track sensor, set the following options:

Option	Description
Pointing Type	Targeted
Boresight Type	Tracking

6. Highlight the DSN_Cal facility in the *Available Targets* list and click the right-arrow button to assign it as a target. Repeat this process for the other two facilities.

7. When you finish, click *Apply*.

8. On the *2D Graphics/Attributes* page change the color to be different from that of the previously created 'image' sensor and click *OK*. This will help when viewing the sensor in the map window. It is also help to check the *Fill* box, so the coverage is displayed as filled in on the map.

9. Animate the scenario. Notice that when the satellite gets within range of any DSN facility, the track sensor pattern appears. The pattern of the image sensor, which is non-tracking, is always displayed.

10. Create a sensor for the DSN_Cal facility and rename it 'uplink.'

11. Right click the uplink sensor, select *Properties*, go to the *Basic/Definition* page, define the sensor as *Simple Conic* with a *Cone Angle* of 80 deg. Click *Apply*.

12. Go to the uplink sensor's *2D Graphics/Projection* page. Under "*Extension Distances*", make sure the "*Use*" box is checked. Change "*Project to:*" to "*Object Altitude*", then select the LEO satellite under *Projection Altitude Object*. Click *OK*. This sets the altitude of the sensor's projection to the height of the LEO satellite.

Reset and animate the scenario to observe the sensor display over time in the 2D map window. Reset the scenario when finished.

Compute Sensor Access

Previously we computed access between satellites and facilities. We will now calculate access for some of the other objects that we have created.

1. Highlight the 'image' sensor in the *Object Browser*, right click and select *Access* from the menu.

2. Highlight all three DSN facilities and click the *Compute* button (you may need to hold down ctrl or shift to highlight them all simultaneously).

3. Under *Graphics*, uncheck *Inherit Settings from Scenario,* then make sure that all three boxes below that are checked. The 2D Map window updates to display the access as the highlighted portion of the ground track. Note the intersections of the sensor pattern and each of the DSN facilities.

4. To view a report of the access time, click on the *Access...* button in the *Reports* box. A report listing the access times between the objects displays.

5. Close the report

6. Click the *Remove All* button and click *Close* to close the window. Reset the 2-D Map window.

7. Right click the uplink sensor and open the Access tool.

8. In the *Available Object* list, select Moon. Click *Compute*.

9. Click on the *Access...* button in the *Reports* box.

Quiz: How long is the Access time between the sensor & the moon?

11. Close the report and click the *Remove Access* button in the Access window.

12. Click *Close* to close the window.

Create Reports and Graphs

Creating Reports

1. In the *Object Browser* window, select the MEO satellite.

2. Right click on MEO and go to the *Report & Graph Manager* menu.

3. In the *Installed Styles* list, select *Fixed Position Velocity* Report (not Graph) and click the *Generate* button. (To see only Reports, uncheck the *Show Graphs* box)

4. After reviewing the report close it and the Report tool window.

Warning: It is recommended that you not make changes to default styles. Instead either make a copy of an existing style to modify, or simply create a new style.

Warning 2: When creating a report, it is a good idea to pay attention to the time period and time interval that the report will produce. STK may crash if it attempts to produce data for a large time period at a very small time interval. The 'Time Period…' button beneath the 'Create…' button allows the user to specify the time period of interest.

Creating Graphs

1. In the *Object Browser* window, select the LEO satellite.

2. Right click and go to the *Report & Graph Manager* Menu.

3. In the *Installed Styles* list, select *Solar AER* (graph, not report this time) and click the *Generate* button.

4. After reviewing the graph close it and the Graph tool window.

Answer 3: The two objects have access for approximately 33482 seconds.

Congratulations! You are finished with Lab 1. We will be using the DSN Facilities and various sensors in future labs. Feel free to explore STK's other capabilities and I hope you enjoy using the software.