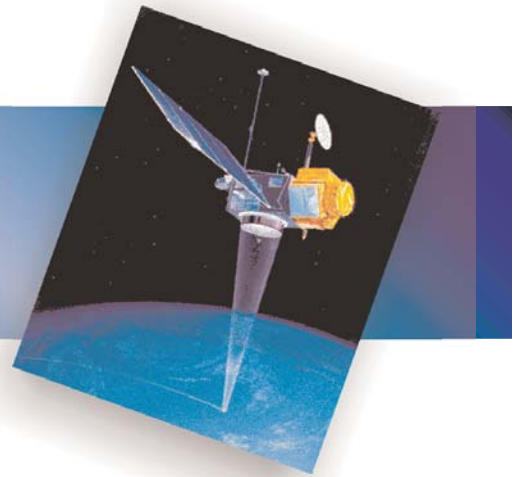# Satellites and Satellite Tool Kit

LEARNING OUTCOMES

After completing this chapter, you should be able to:
- Define an orbit.
- Describe different orbits.
- Discuss the Hubble Telescope's contributions.
- Define STK.
- Describe how STK can be used.
- Apply STK technology to predict satellite passes.

In 1957, the Russians launched Sputnik, the first artificial (manmade) satellite. Since then, scientists have used the term satellite for any object that orbits the Earth, natural or artificial. The moon is the Earth's only natural satellite. So, all the rest of the satellites are manmade. In this chapter, we will only discuss artificial satellites and their orbits.

Sputnik (1957)

A few months after Sputnik, the United States launched *Explorer* 1, America's first satellite. Now thousands of satellites are orbiting Earth. Satellites are designed with a purpose. They have a mis-
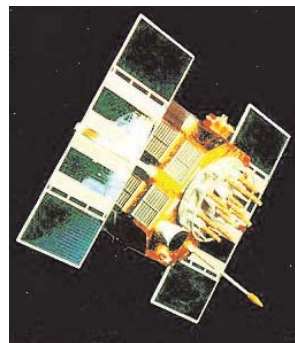

Explorer I **(1958)**

sion to perform. For instance, their purpose might be communication, navigation, observation or scientific. These are four broad categories of purposes, which all involve satellites collecting information and relaying it back to Earth.

Satellites are gathering and transmitting amazing information. Technology has become so sophisticated. Communications satellites (COMSATs) have been around since 1958, and their uses have grown tremendously. COMSATs still transmit for radios and televisions, but they also transmit for the internet and cellular phones. Additionally, they provide command and control for military forces, and they provide links to other spacecraft.

***Artists rendering of an Advanced Communication Technology Satellite***

About thirty years ago, the US Air Force, in association with the other branches of service, created a new global navigation system called NAVSTAR Global Positioning System (GPS). This system provides navigation and timing information to both civilian and military users worldwide. Position velocity, and time can be precisely determined.

Navstar

satellites give precise reference points and continuously broadcast position and time data. The GPS satellites calculate a three-dimensional position, which is given in latitude, longitude, and altitude. GPS is rapidly replacing all other navigational systems. Virtually all ships and airlines use GPS technology and trucking fleets and law enforcement agencies use it. Search and rescue teams, military, and even hunters and hikers use GPS.
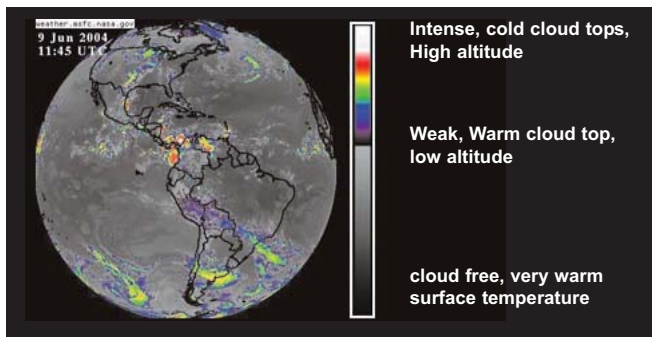
A type of observation satellite is the weather satellite. Weather satellites have become very important. They add tremendously to the accuracy of weather forecasts. Every weather station uses satellites. Turn on any news channel weather report and they will mention what the satellites are depicting. Of course, the weather satellites are particularly helpful with severe storms and hurricanes.
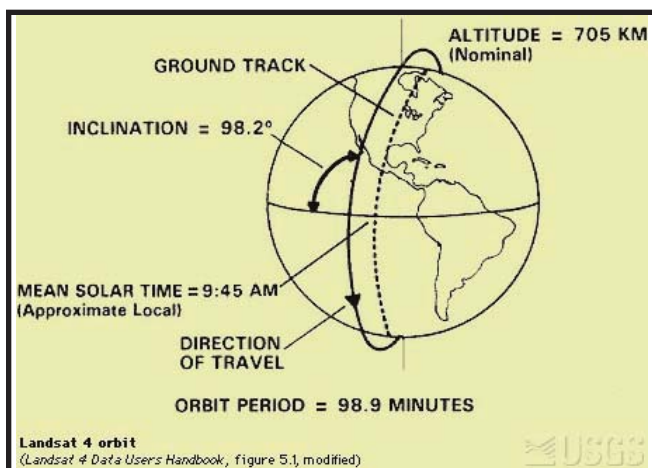
Landsats Orbit

Another type of observation satellite is the multi-spectrum-imaging satellite; an example of this is the Landsat series. Landsats locate natural resources and monitor other conditions on the Earth's surface.

Scientific satellites orbit to gain information, and there are literally hundreds of examples we


The Hubble Space Telescope

could discuss, but only one will be mentioned before going into a discussion of orbits. This last example is the Hubble Space Telescope. Hubble was launched in 1990, and thanks to over 90 hours of on-orbit service calls by Space Shuttle astronauts, Hubble continues to be a state-of-the-art model.

Hubble orbits at 600 kilometers or 375 miles above Earth, working around the clock to unlock the secrets of the universe. It uses excellent pointing precision, powerful optics, and modern, up to date instruments to provide stunning views of the universe that cannot be duplicated using ground-based telescopes or other satellites.

Hubble travels at 5 miles per second or 18,000 miles per hour. A trip from Los Angeles to New York takes 10 minutes. Hubble completes one full orbit every 97 minutes. In an average orbit, Hubble uses about the same amount of energy as twenty-four 100-watt light bulbs. To locate Hubble click on: **http://hubble.nasa.gov** and go to Hubble Operations and get an instantaneous reading.

Hubble was designed to last 20 years, so it only has a few years left. However, Hubble has given scientists the best pictures ever received about space. Hubble has taken over 300,000 separate observations and has observed more than 25,000 astronomical targets. The latest astronomical findings are discussed in Chapter 5, and in most cases those discoveries can be credited to the Hubble telescope.

So, we have thousands of satellites in space. What is keeping them from bumping into each other? Well, first of all space is a very vast place,
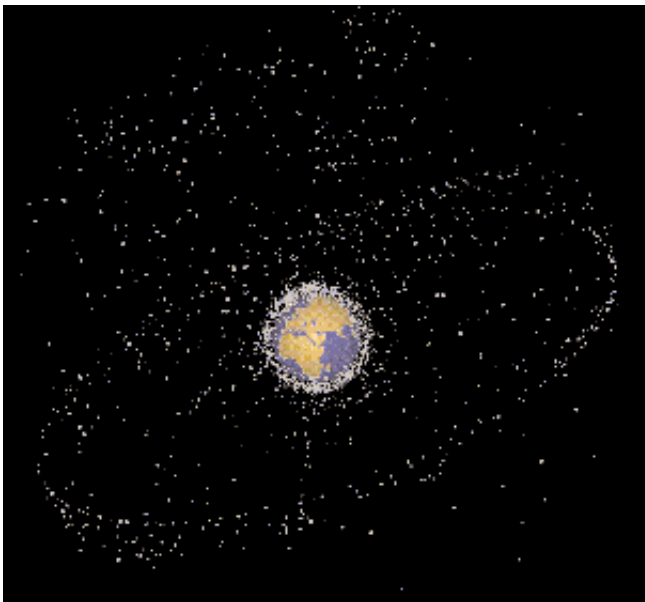
Space debris

and there is plenty of open space where satellites haven't gone yet. And secondly, these thousands of satellites are on different orbits around the Earth. An orbit is defined as a path described by one body in its revolution about another body.

Ancient astronomers determined that the motion of celestial bodies was not random. They studied the motion and measured the movement of planets. In 1611, German astronomer Johannes Kepler discovered several objects moving around Jupiter. From this, Kepler created rules of motion for planets, but all celestial bodies, including artificial satellites obey them.

Kepler's First Law states: The orbit of each planet is an ellipse, with the sun at the focus. In an elliptical orbit, the satellite's altitude, velocity and speed are not constant. Therefore, the shape varies. When orbital variations in speed are small, the orbit shape is nearly circular, but when the speed variations increase, the orbit becomes more elliptical.

During an orbit, the orbiting object reaches a high point and a low point. Its highest point is called the apogee, and its lowest point is called its perigee. The apogee represents the point where the object is the farthest away from the body being

Apogee   Perigee

orbited. The perigee represents the point where the object is the closest to the body being orbited.

Gravity gives the orbit its shape. An example of a bullet fired from a gun helps to explain this. As the bullet is traveling in a straight line, gravity pulls the bullet toward the center of the earth. The combination of the bullet's speed and gravity create a curved flight path. The curvature of the bullet's path can be changed by adjusting the bullet's speed. Matching the curve of the flight path to the curve of a planet is the basic concept of an orbit.

Orbits have different ranges of altitudes: low, high, and medium. Low earth orbits **(LEOs)** are below 300 miles. The International Space Station moves in a low earth orbit at about 250 miles above Earth, and the Space Shuttle flies in low earth orbit. A high earth orbit **(HEO)** is above 23,000 miles. Geostationary or geosynchronous orbits are high earth orbits. Most communication satellites and some weather satellites are found here. Also some astronomy satellites are found in high earth orbit. Medium earth orbits **(MEOs)** are in between the low and high orbits. This category ranges from orbits of a few hundred miles to a few thousand miles. Some communication and telecommunication satellites operate in medium earth orbit. Also, the Hubble Space Telescope moves in a medium orbit at about 375 miles above Earth.

Types of Orbits

Sunsynchronous

This orbit synchronizes the satellite's orbit with the Earth's orbit around the sun. The light from the sun forms an angle with the satellite's orbital plane. In this orbit, this plane turns as the Earth moves around the sun. The turning maintains a constant angle between the light from the sun and the orbit plane creating the same lighting conditions for the satellite to view year around. Sunsynchronous orbits are used by earth observation and weather satellites.

Geosynchronous

In this orbit, the rotation of the satellite is synchronous with the rotation of the Earth. The satellite's period is 23 hours and 56 minutes, the same time as one revolution of the Earth. When the inclination of a geosynchronous orbit is zero degrees, the satellite appears to remain over the

same spot on the equator for the entire orbit and is refered to as a geostationary orbit. Remember, both the satellite and the spot on the equator are revolving around the axis of the Earth. From the ground, a satellite in this orbit appears stationary in the sky. The high altitude of this orbit gives a satellite a large field of view, and the stationary appearance makes it easy to find and aim a radio antenna at the satellite. These two features make the geostationary orbit very useful to communication satellites.

Molniya

This is a highly elliptical and highly inclined orbit. Molniya is the Russian word for orbit and the former Soviet Union first used this type of orbit as an alternative to a geosynchronous orbit for communication satellites. The satellite in a highly elliptical orbit moves slowly at apogee and then speeds up near perigee. From the ground, the satellite appears to dwell around the apogee making it easier to locate and track the satellite. The high inclination also gives the satellite a good field of view of the polar regions of the Earth.

Circular - an orbit that maintains a virtually constant altitude above the Earth's surface.

Elliptical - any closed orbit that is not circular. All elliptical orbits around Earth have an apogee and a perigee.

Equatorial - The satellite travels from west to east over the Earth's equator. Some satellite orbits incline to the Equator a certain number of degrees.

Now, let's put some of this information you have learned to more practical use. Let's talk about Satellite Tool Kit and some of the amazing applications it provides.

SATELLITE TOOL KIT (STK)

Satellite Tool Kit, developed by Analytical Graphics, Inc. (AGI), is the leading commercial off-the-shelf software solution for the aerospace industry. As the industry standard, AGI's software supports end-to-end satellite systems from mission planning through operations. Basic applications include tracking satellite locations, determining when they have access to certain areas, and analyzing what satellites can see at any point in time.

STK makes it easy to analyze complex land, sea, air, and space scenarios and determine optimal solutions. It provides the ability to present results in graphical and text formats for easy interpretation and analysis. It is used by tens of thousands of professionals worldwide. STK is used by over 70 major universities, including the U.S. Air Force Academy, NASA, CIA, and all branches of the military, government and commercial operations working in space.

STK provides the analytical engine to calculate data and display multiple 2-D maps that visualize various time-dependent information for satellites and other space-related objects such as launch vehicles, missiles, and aircraft. STK's core capabilities include generation of position and attitude data, acquisition times, and sensor coverage analysis for any of the objects modeled in the STK environment. The integrated STK software provides tools to support all aspects of the aerospace community, ranging from system design and concept to real-time operations.

To pique your interest a little we have included a couple of exercises to demonstrate some of STK's basic capabilities. We hope you will enjoy the exercises and visit the STK website. In order to perform these STK scenarios and activities, you you will need a STK 6.2 disk. A copy of this disk can be obtained from your CAP wing Director of Aerospace Education (DAE).Your wing DAE has a few copies that are available to borrow. Please use the disk, learn about STK, and then return it to your DAE so others can also benefit from the software program.

Before you begin your journey into the wonderful world of STK, CAP/AE would like to thank a few very important people for making this journey possible. First, we would like to thank CAP Col. Drew Alexa for his tireless efforts to bring this marvelous educational tool to CAP. It was his vision and dedication that made it happen. We'd like to thank CAP Lt. Col. Mike McNeely for developing the initial scenarios that were used as the foundation for changing these current
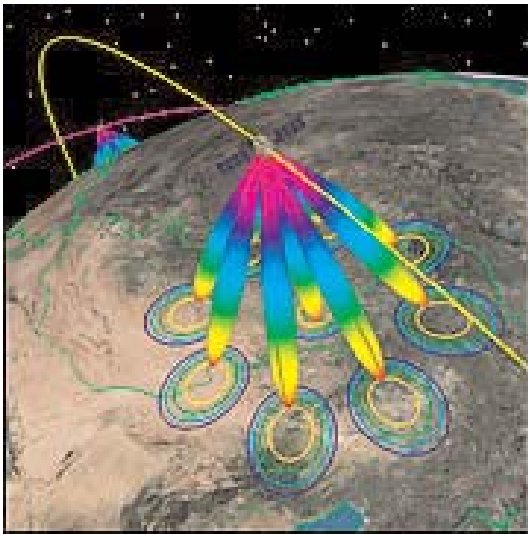
Laser communication link model analyses wide-band satellite crosslinks in visible near-infrared, and infrared wavelengths.

scenarios to the STK 6.2 format. Mike continues to be a strong advocate for space and STK and presents STK seminars in many CAP settings. Finally, we'd like to thank Paul Graziani, President and CEO of Analytical Graphics, Inc, makers of STK, for his generosity and strong partnership with CAP. He and his terrific staff continue their outstanding support to CAP. Thanks to all of you for bring this wonderful educational opportunity to our cadets.

For learning more about STK and AGI go to **www.stk.com** or **www.agi.com.**

STK
Scenario One

An important part of Orbital Mechanics is orbital geometry. Included in this section are four activities describing different concepts in orbital geometry: semi-major axis, eccentricity, inclination and perigee. STK can help you understand these concepts. We hope you enjoy the following scenarios.

This portion of the lesson plan illustrates the satellite concepts you just learned about. To do this, you will run six self-guided scenarios using STK/VO software. Each scenario will help you visualize the characteristics associated with the six orbital elements. As you recall, the major concepts were: (1) The six classical elements uniquely characterize an orbit. (2) The classical

elements have an influence on the satellite ground track pattern. The instructions below are a step-by-step guide to help you view and understand the scenarios.

Scenario One helps you visualize the semi-major axis influences on an orbit. Specifically:
1. Changes in the semi-major axis change the altitude of an orbit.
2. Changes in the semi-major axis alter the satellite's field of view (FOV).
3. Changes in the semi-major axis alter the satellite's geographic point location on a flat map.

1. Execute Scenario One by selecting **File/Open/LocalDiskC/Scenario\Lesson3\ axisR\semi-major_axisR.sc**
- Select View (3rd button, top row) then select New 3D Graphics Window from the drop down menu.
-Enlarge the screen and rotate the earth until Korea is centered on the earth by placing the cursor on the globe and left clicking the mouse.
-Move the mouse to the right or left to orient the

globe. Depicted in BLUE is a LEO satellite with a 6700 km semi-major axis.

2. Select START. (4th blue button, row 3)
-Observe the speed of the satellite. The semi-major axis determines the altitude, which in turn determines how long it takes the satellite to complete an orbit. (Note: You may slow down or speed up the motion of the satellite by using the the 6th and 7th blue button, row 3.)

3. Select PAUSE (3rd blue button, row 3)
-The next few steps will enable you to change the semi-major axis and observe the effects.

4. In the object browser window, highlight LEO. If you do not see the object browser window, select View (3rd button, row 1) then select Object Browser from the drop-down menu. Right click the mouse and select copy. Right click again and select paste. A LEO1 file will appear. Highlight LEO1 and then right click the mouse. Select rename from the drop-down menu. LEO 1 will be highlighted in BLUE and the cursor will flash. Now type in MEO and then select OK.

5. Highlight MEO, left click the mouse and select PROPERTIES and then 2D GRAPHICS. Select ATTRIBUTES.

6. Change the BLUE color to MAGENTA. Select APPLY and OK.

7. In the OBJECT BROWSER window, highlight the MEO SENSOR 1. Right click the mouse and select PROPERTIES and then BASIC and then DEFINITION. Change the outer half angle parameter to 15.0 degrees. This action is required to ensure the satellite's FOV is an appropriate size for the visual representation. Select APPLY and OK.

8. In the OBJECT BROWSER once again, highlight MEO. Right click the mouse and select PROPERTIES and then BASIC. Displayed are all the basic orbital elements necessary to define an orbit. Currently the MEO orbital elements are a carbon copy of the LEO orbital data.

9. Now change the semi-major axis to 20372 km. This value reflects an appropriate MEO altitude. Next select 2D GRAPHICS and then select

ATTRIBUTES. Change the color from BLUE to MAGENTA.

10. Select APPLY and OK.

11 Select RESET. (You can decrease the size of the globe to show both orbits by placing the cursor on the globe, left click the mouse and move it forward. Moving the mouse backward will enlarge the globe.) Select RESET.

12. Select START.
In addition to the LEO, the MEO is depicted in MAGENTA. Compare the relative speeds of each orbit. The LEO satellite travels faster than the MEO satellite because the LEO semi-major axis is smaller. Consequently, the smaller the semi-major axis, the lower the altitude and the shorter orbital period.

13. At time 15:03, select PAUSE.
Also note that the semi-major axis (altitude) influences the field of view size (FOV). The MEO satellite FOV is comparatively larger than the LEO satellite FOV.

14. Select the 2D GRAPHICS View.
The 2D view is a mercator projection map. Basically it is the globe projected on a flat map. The unique characteristic of a mercator projection is that the distance between latitude lines is equal, making it easy to perform any calculations. The 2D view of the Earth is used to show the satellite's orbit projected over geographic areas. The semi-major axis affects the ground track in a few ways. First, it shows the speed of a satellite. Note how quickly the LEO satellite, depicted in BLUE, moves across its track compared to the MEO satellite. Second, it determines the ground track repeating pattern. Note the LEO satellite moves slightly west with each pass, giving the appearance of successive ground tracks.

15. Select PAUSE.

16. Review the scenario as often as necessary. Repeats steps 9-14 to change the value of the semi-major axis again to different altitudes. Once complete with the scenario, select PAUSE.

17. View the scenario as often as needed. Close out. Do not save the file.

STK
Scenario Two

Scenario two helps you visualize how eccentricity affects the shape of the orbit. Specifically: (**1**) changes to the eccentricity value from zero to one changes an orbit from circular to eccentric; (**2**) the eccentricity values describes the symmetry of the orbit. To initiate the scenario, complete the following steps:

1. **File\Open\LocalDiskC\Scenario\Lesson3\ eccentricityR\eccentricityR.sc** If you forget how to complete a step, refer back to scenario one for step by step instructions.

2. Select **VIEW\NEW 3D GRAPHICS.** Enlarge the screen.

3. Orient the globe so the African continent is at the nine o'clock position. Then select **START**. Depicted in **RED** is the **MEO1** orbit. The eccentricity value is 0.01, representing a circular orbit. Because the orbit is circular, the earth is at the center of the orbit. (Zoom allows you to see the entire orbit.)

4. The next few steps will enable you to change the eccentricity value to a 0.5 value.

5. Highlight **MEO_1** in the **OBJECT BROWSER** screen.

6. Right click the mouse and select **COPY.**

7. Right click again and select **PASTE.** A **MEO_2** file will appear.

8. Highlight **MEO_2** and right click the mouse. Select **PROPERTIES\ 2D GRAPHICS\ ATTRIBUTES**. Change the color to **MAGENTA**.

9. Select **BASIC\ORBIT**.
Displayed are all the basic orbital elements necessary to define an orbit.
Currently, the **MEO_2** orbit has the same orbital data as **MEO_1**.

10. Change the eccentricity value to **0.5.**

11. Select **APPLY** and then **OK**.

12. Select **RESET**, then **START**.
The **MAGENTA** orbit depicting an eccentricity value of .5 represents an elongated orbit. Compare the two orbits. For the **MEO_2** orbit, the earth is no longer in the center of the orbit, illustrating its elongated orbit.

13. The remaining steps will change the eccentricity value from **.5** to **.65**.

14. Select the **MEO_1** icon in the **OBJECT BROWSER** screen.

15. Right click and select **EDIT\COPY**. Right click and select **PASTE**. A **MEO_3** will appear.

16. Highlight **MEO_3,** right click and select **PROPERTIES\2DGRAPHICS\ATTRIBUTES**. Change the color **RED** to **DARK SEA GREEN**.

17. Select **BASIC\ORBIT**.

18. Change the Eccentricity value from **0.0** to **0.65**.

19. Select **APPLY** and then **OK.**

20. Select **RESET**. Then **START.**
The **DARK SEA GREEN** orbit represents the highly eccentric orbit. Observe how elongated the orbit is compared to the previous orbits.

21. Select the **2D** map and select **RESET**.
Eccentricity determines a ground track's symmetry. In turn, it defines how much ground will be covered in a period of time throughout the orbit. For example, if the eccentricity parameter equals zero, a satellite will sweep over equal areas in equal time. In contrast, if the eccentricity parameter is close to one, the satellite will dwell over the apogee point. Thus, the area covered in this portion of the orbit is small. Conversely, the satellite will move through its perigee point rapidly and cover more surface area in an equal amount of time.

22. Select **START**.

23. At time **2 Jan 00:10**, all three satellites will be in view.
The earth map shows each satellite's ground track

for one complete pass, specifically, pass number three. The **MEO_1** orbit will sweep out an equal area in equal time. However, **MEO_3,** representing the highly eccentric orbit will initially move out quickly until its apogee point, where it dwells for a long time over one geographic spot, approximately 20 degrees longitude.

24. At time **2 Jan 08:05** select **PAUSE**.
All satellites have completed one pass and are in the same approximate position to each other. Each orbit completes its pass in the same amount of time. Only the speed during the orbit varies for the more eccentric orbit.

25. Review the scenario as often as needed. Close out by selecting **FILE/CLOSE.** Do not save the file.

STK

Scenario Three

Scenario three helps you visualize how the inclination affects the orientation of the orbit. Specifically: (**1**) changes to the inclination value changes the tilt of an orbit from the equatorial plane; (**2**) from a flat perspective, the extreme northern and southern latitudes a satellite will cover equates to the inclination value. For example, if a satellite's inclination is 28.5 degrees, it will travel no further north than 28.5 degrees north latitude and no further south than 28.5 degrees south latitude.

This scenario will illustrate these concepts by having you make changes to the inclination value. To initiate the activity, complete the following steps:

1.**File\Open\LocalDiskC\Scenario\Lesson3\ inclinationR\ inclinationR.sc**. If you forget how to complete a procedure, refer to scenario 1 for instructions.

2. Select **VIEW/3D GRAPHICS** and maximize the window.

3. Orient the globe so that the African continent is at nine o'clock position.

4. Zoom out on the globe until the word **LEO_1** is visible.
 You are viewing a **LEO** orbit at a zero inclination. Observe its relation to an imaginary equatorial line. The **LEO_1** satellite, having a zero inclination, parallels the equator. It does not tilt away from the equator.

5. The next few steps will enable you to change the inclination value.

6. In the **OBJECT BROWSER** window, highlight the **LEO_1** icon. Right click and select **COPY.**

7. Right click again and select **PASTE**. **LEO_2** will appear. Change the name to **LEO_35**.

8. Highlight **LEO_35.** Right click and select **PROPERTIES\2DGRAPHIC/ATTRIBUTES**. Change the color RED to MAGENTA.

9. Select **BASIC\ORBIT.** This orbit tab represents all the parameters required to define the orbit. Currently, the **LEO_35** parameters are the same as **LEO_1**.

10. Change the inclination value to **35.0 DEGREES**.

11. Select **APPLY**, then **OK**.

12. Under the **LEO_1** icon in the **OBJECT BROWSER** window, highlight **SENSOR1**.

13. Right click and select **PROPERTIES\2D GRAPHIC\ATTRIBUTES**. Change the color from RED to MEDIUM ORCHID.

14. Select **APPLY** and **OK**.

15. Toggle to the **2D** map.

16. Select **RESET**, then **START.**
By observation, you can view the 35-degree tilt of the orbit with respect to the imaginary equatorial line or the **LEO_1** orbit. As **LEO_35** travels in its orbit, it is able to view 35 degrees above and below the **LEO_1** orbit.

17. Select **PAUSE.**

18. The next few steps will enable you to compare a highly inclined orbit to the previous two orbits.

19. In the **OBJECT BROWSER** window, highlight **LEO_35.**

20. Right click and select **COPY.**

21. Right click again and select **PASTE**. **LEO_2** will appear. Change the name to **LEO_80.**

22. Highlight **LEO_80**. Right click and select **PROPERTIES\2DGRAPHICS\ATTRIBUTES.** Change the color to DARK SEA GREEN.

23. Select **BASIC\ORBIT.** The orbit tab is displayed. Presently, the orbital parameters reflect the same values as the **LEO_35.**

24. To define a highly inclined orbit, change the inclination value to **80.0** degrees.

25. Select **APPLY** and **OK**.

26. Highlight **SENSOR1** under the **LEO_80** icon. Right click and select **PROPERTIES\2DGRAPHICS\ATTRIBUTES**. Change the color to **WHITE**.

27. Select **APPLY** and **OK.**

28. Select the **3D GRAPHICS** map and select **RESET**.
In view are all three orbits. The **LEO_80** orbit is tilted 80 degrees from the equator. It is nearly perpendicular to the equator and nearly parallels the north and south poles. The advantage to a highly inclined orbit is the satellite will travel over higher latitudes.

29. Select **START**.
Observe that the distance north and south of the equator that a satellite can cover is a function of orbital inclination. The greater a satellite's orbital inclination, the greater the satellite's coverage of northerly and southerly latitudes.

30. Select **PAUSE**.

31. Select the **2D** map, then select **RESET**.
The map illustrates the concept of how inclination

bounds the satellite's ground track to its equivalent inclination value. Simply stated, it shows how much area above and below the equator the satellite views.

32. Select **START**.
In this scenario, **LEO_1**, depicted in RED has a zero inclination. Thus, it will remain at the equator, at zero degrees latitude. By comparison, the **LEO_35** satellite, depicted in MAGENTA, will travel north to 35 degrees and then to 35 degrees south, equivalent to it's inclination value. Finally, the **LEO_80** illustrates that the ground track will cover latitudes up to 80 degrees north and south.

33. Select **PAUSE**.

34. View the scenario as often as needed. Close out **FILE/CLOSE.** Do not save the file.

STK
Scenario Four

Scenario four helps you visualize the influences of argument of perigee on an orbit. Specifically, the lesson addresses the primary influence of perigee point placement. To help visualize this concept you will make changes to a **HEO** satellite's argument of perigee. To run the scenario complete the following steps:

1. **File\Open\LocalDiskC\Scenario\Lesson3\argperigee\ArgperigeeR.sc**. If you forget how to do a procedure, please refer to scenario one for instructions.

2. Select **VIEW\NEW 3D GRAPHIC** map. Maximize the window.

3. Orient the globe so that the North American continent is centered on your screen.

4. Zoom out until three-fourths of an orbit is in view.

5. Displayed is a **HEO** orbit.
The argument of perigee value is 270 degrees, resulting in a perigee point in the southern hemisphere. By definition, the argument of perigee is measured from the ascending node to the perigee

point in the direction of satellite motion. Now look at your display and imagine a horizontal line around the center of the earth. This line represents the equator. The point at which that line crosses the orbit is the ascending node. From the ascending node, use a pointer and trace a movement around the orbit 270 degrees in a counter clockwise direction. Your pointer is now at the southern point in the orbit, representing the perigee point.

6. Select **START**. The satellite will travel fastest at its perigee point. Thus the South Pole region will have very little coverage.

7. The next few steps will have you change the argument of perigee value.

8. In the **OBJECT BROWSER** window, highlight **HEO270**.

9. Right click and select **COPY**.

10. Right click again and select **PASTE**. A **HEO1** will appear. Change the name to **HEO90**.

11. Highlight **HEO90**, right click and select **PROPERTIES\2DGRAPHICS\ATTRIBUTES**. Change the color from **RED** to **MAGENTA.**

12. Select **APPLY** and **OK**.

13. Highlight **SENSOR1.** Right click and select **PROPERTIES\2D GRAPHICS\ATTRIBUTES**. Change the color to **HOT PINK**. Select **APPLY,** then **OK.**

14. Highlight **HEO90**, right click and select **PROPERTIES\BASIC/ORBIT**. The orbit tab displays all the parameters defining this orbit. However the **HEO90** orbit is a duplicate of the **HEO270**.

15. Change the Argument of Perigee value to **90 degrees**. Observe the effects when you change the argument of perigee.

16. Select **APPLY,** then **OK**.

17. Reset, then select **START.**
In comparing the two orbits, the perigee points are

directly opposite from each other. The MAGENTA orbit, represents a satellite with a 90 degree argument of perigee. The majority of its coverage will be in the southern latitudes as it approaches apogee.

19. Select **PAUSE**.

20. Toggle to **2D** map.
Observe where the perigee points are for each satellite. The perigee point defines the point in the orbit at which the satellite will spend the least amount of time. In selecting a satellite orbit, you should consider how much time a particular point on the earth needs to be viewed. Note: a circular orbit does not have a defined argument of perigee. Can you explain why? Hint: The apogee and the perigee are equal values.

21. View as often as needed. When complete, select the **PAUSE** button. Close out by selecting **FILE/CLOSE.** Do not save the file.