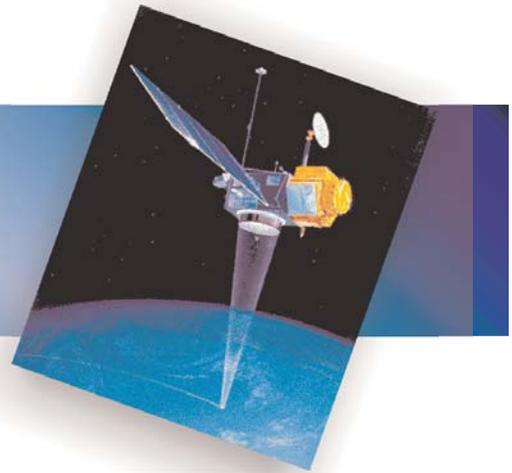# Satellites and Satellite Tool Kit

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.

They have a mission 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.

Artists rendering of an Advanced Communication Technology Satellite

Additionally, they provide command and control for military forces, and they provide links to other spacecraft.

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

Sputnik (1957)

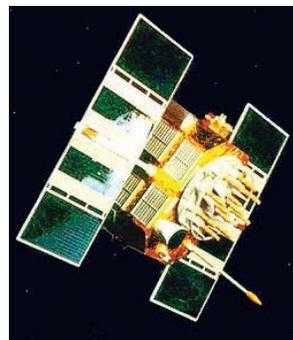chapter, we will only discuss artificial satellites and their orbits.

A few months after Sputnik, the United States launched *Explorer* 1, America's first satellite. Now, 45 years later, thousands of satellites are orbiting Earth. Satellites are designed with a purpose.

Explorer I **(1958)**

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,

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.
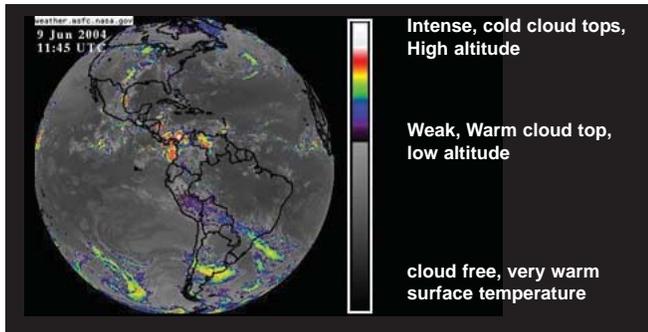
A type of observation satellite is the weather satellite. Weather satellites have become very im-portant. They aid tremendously to the accuracy of weather forecasts. Every weather station uses satellites. Turn on any news channel weather report and they will mention what the satellites are depicting. Of course, the weather satellites are particularly helpful with severe storms and hurricanes.
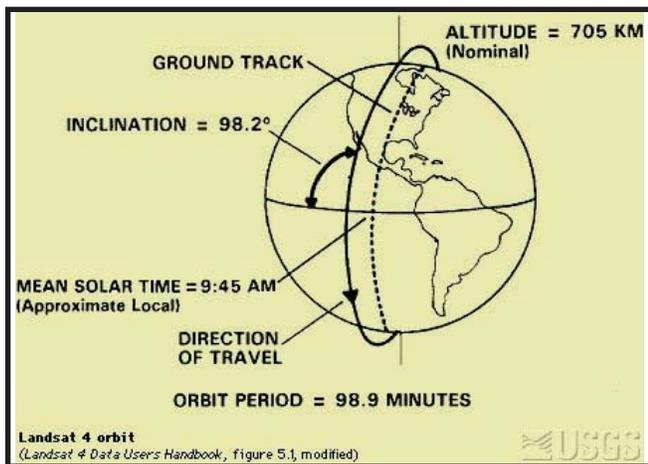
Landsats Orbit

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 I want to mention only one more 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: **www.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,
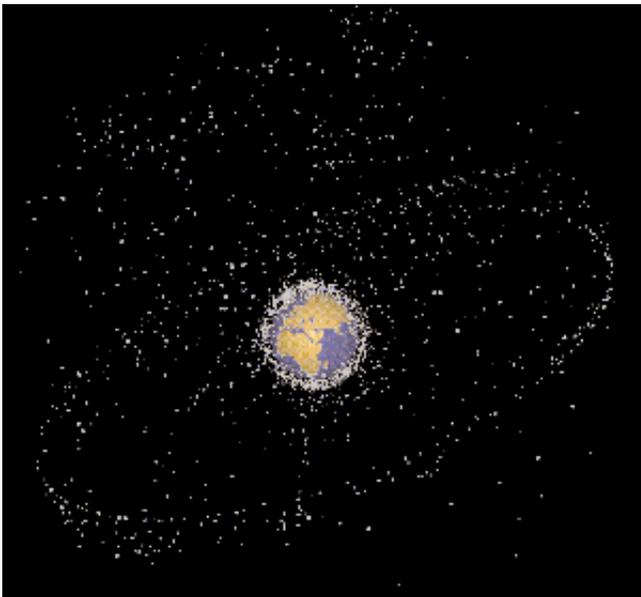
Space debris

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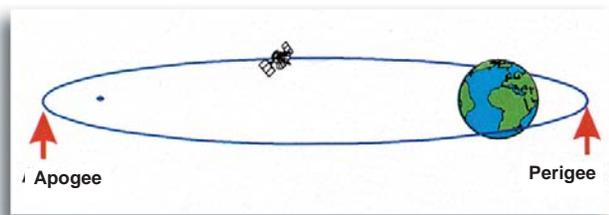
orbited. The perigee represents the point where the object is the closest to the body being orbited.

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 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 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 orbits 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.

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

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 5.0 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.

STK
Scenario One

An important part of Orbital Mechanics is orbital geometry. Included in this section are four activities describing different concepts in
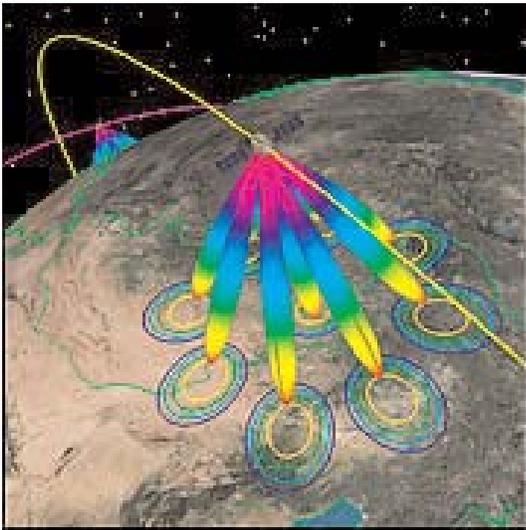
Laser communication link model analyses wide-band satellite crosslinks in visible near-infrared, and infrared wavelengths.

orbital geometry: semi-major axis, eccentricity, inclination and perigee. STK can help you understand these concepts. We hope you enjoy the following scenarios.

This activity 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, **(3)** changes in the semi-major axis alter the satellite's geographic point location on a flat map.

1. Execute scenario one by following the **STARTING AND USING SATELLITE TOOL KIT** instructions and loading **Scenario\ Lesson3\ axisR\semi- major_axisR.sc**
    - Select the **VO** map and rotate the earth until Korea is centered on the earth.
    - Depicted in **blue** is a **LEO** satellite with a 6700 km semi-major axis.

2. Select **START**
    - 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.

3. Select **PAUSE**
    - The next few steps will enable you to change the semi-major axis and observe the effects.
4. Select the **Satellite Tool Kit** window.

5. Highlight **LEO.** Be sure the **+ (plus)** symbol is

indicated. Thus, this action will enable all linking files to be copied in the next step. If the **- (minus)** symbol is displayed, click once **ON** the minus sign to get the plus sign back.

6. Select **EDIT,** and **COPY**.

7. Highlight **semi-major_axisR.**

8. Select **EDIT** and **PASTE.**

9. A **LEO1** file will appear. Change the name to **MEO.**
    - To change the name
    - Click **ONCE** on the center of the name. **LEO1** will be highlighted in **blue** and cursor will flash.
    - Type in **MEO,** then point to the icon before the name and click once.
10. Select **PROPERTIES** and then **GRAPHICS.**
11. Change the **blue** color to **magenta.**

12. Select **APPLY and OK.**

13. At the **MEO** icon, click on the +. A **Sensor1** icon appears.
14. Highlight **Sensor1**.

15. Select **PROPERTIES** and then **BASIC**.

16. Change the outer half angle parameter to15.0 degrees. This action is required to ensure the satellite's **FOV** (field of view) is an appropriate size for the visual representation.

17. Select **APPLY** and **OK**.

18. Once again, highlight **MEO**.

19. 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.

20. Now change the semi-major axis to **20372 km**. This value reflects an appropriate **MEO** altitude.

21. Select **APPLY** and **OK**.

22. Toggle to the **VO** map and select **RESET**.

23. 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.

24. 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. Again, as described in lesson 1, the greater the altitude or semi-major axis, the larger the satellite's FOV.

25. Select the **2D** map.
    - The **2D** map 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. Earth view map 1 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.

26. Select **PAUSE.**

27. Review the scenario as often as necessary. Repeat steps 4-25 to change the value of the semi-major axis again to different altitudes. Once complete with the scenario, select **PAUSE**.

28. View the scenario as often as needed. Close out according to the instructions in **STARTING AND USING SATELLITE TOOL KIT.**
    Do not save the file. Saving the file causes problems for the next user.

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. Load **Scenario\Lesson3\eccentricityR \eccentricityR.sc**

2. Select the **VO** map. Now select **RESET**.
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.

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

5. Select the **Satellite Tool Kit** window.

6. Highlight **MEO_1**.

7. Select **EDIT** and **COPY**.

8. Select **EDIT** and **PASTE**. A **MEO_11** file will appear. Change the name to **MEO_2**. Refer to step9 of Scenario One if you need instructions on how to do this.

9. Select **PROPERTIES** and **GRAPHICS**. Change the color **red** to **magenta**.

10. Select **APPLY** and **OK**.

11. Select **PROPERTIES** and **BASIC**.
    - Displayed are all the basic orbital elements necessary to define an orbit. Currently, the **ME0_2** orbit has the same orbital data as **MEO_1**.

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

13. Select **APPLY** and then **OK**.

14. Toggle to the **VO** map.

15. 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.

16. The remaining steps will change the eccentricity value form **.5** to **.65**.

17. Select the **Satellite Tool Kit** window.

18. Select the **MEO_1** icon.

19. Select **EDIT** and **COPY**. A **MEO_11** will appear.

20. Change the **MEO_11** name to **MEO_3**.

21. Select PROPERTIES and then **GRAPHICS**. Change the color **red** to **Dark Sea Green**.

22. Select **APPLY** and then **OK**.

23. Select **PROPERTIES** and then **BASIC**.

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

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

26. Toggle to the **VO** map and select **RESET**.
    - The Dark Sea Green orbit represents the highly eccentric orbit. Observe how elongated the orbit is compared to the previous orbits.

27. 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.

28. Select **START**.

29. 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.
    - 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.

30. Review the scenario as often as needed. **Close out** according to the instructions in **STARTING AND USING SATELLITE TOOL KIT.**

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. Load **Scenario\Lesson3\inclinationR\ inclinationR.sc**

2. Select the **VO** map and maximize the window.

3. Select **RESET.**

4. Orient the globe so that the African continent is a nine o'clock position.

5. Zoom in 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.

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

7. Select the **Satellite Tool Kit** window.

8. Highlight the **LEO_1** icon. Ensure the **+ sign** appears before you do the next step.

9. Select **EDIT** and then **COPY**.

10. Select **EDI**T and then **PASTE**. **LEO_11** will appear. Change the name to **LEO_35**.

11. Select **PROPERTIES** and **GRAPHICS**. Change the color red to magenta**.**

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

13. Select **PROPERTIES** and **BASIC**. This orbit tab represents all the parameters required to define the orbit. Currently, the **LEO_35** parameters are the same as **LEO_1**.

14. Change the inclination value to **35.0** degrees.

15. Select **APPLY**, then **OK**.

16. From the **LEO_1** icon, click on the **+**. **Sensor1** will appear.

17. Highlight **Sensor1**.

18. Select **PROPERTIES** and **GRAPHIC**. Change the color from red to Medium Orchid.

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

20. Toggle to the **VO** map.

21. 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.

22. Select **PAUSE**.

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

24. Select the **Satellite Tool Ki**t window.

25. Highlight **LEO_35**. Ensure the **+** symbol is indicated. Thus, this action will enable all linking files to be copied in the next step.

26. Select **EDIT** and **COPY**.

27. Select **EDIT** and **PASTE**. **LEO_351** will appear. Change the name to **LEO_80**.

28. Select **PROPERTIES** and **GRAPHICS**. Change the color from **magenta** to **Dark Sea Green.**

29. Select **APPLY** and **OK**.

30. Select **PROPERTIES** and **BASIC**. The orbit tab is displayed. Presently, the orbital parameters reflect the same values as the **LEO_35**.

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

32. Select **APPLY** and **OK**.

33. Highlight **Sensor1** under the **LEO_80** icon.

34. Select **PROPERTIES** and **GRAPHICS**. Change the color from **red** to

35. Select **APPLY** and **OK**.

36. Select the **VO** 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.

37. 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.

38. Select **PAUSE**.

39. 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.

40. Select **START**.
    - In this scenario, **LEO_1**, depicted in red has a zero inclination. This, 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.

41. Select **PAUSE**.

42. View the scenario as often as needed. Close out according to the instructions in **STARTING AND USING SATELLITE TOOL KIT**. **Do not save this 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. Load **Scenario\Lesson3\argperigee\ ArgperigeeR.sc.**

2. Select the **VO** map and **RESET**.

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. Select the **Satellite Tool Kit** window.

9. Highlight **HEO270**.

10. Be sure the **+** symbol is indicated. This action will allow all linking files to be copied in the next step.

11. Select **EDIT** and **COPY**.

12. Select **EDIT** and **PASTE**. A **HEO2701** will appear. Change the name to **HEO90**.

13. Select **PROPERTIES** and then **GRAPHICS**. Change the color from red to magenta.

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

15. If the + symbol appears next to HEO90, click on it. Sensor1 appears. If the + symbol isn't there, Sensor1 will already be visible.

16. Highlight **Sensor1.**

17. Select **PROPERTIES** and then **GRAPHICS**.

18. Change the color to **Hot Pink**.

19. Highlight **HEO90**.

20. Select **PROPERTIES** and then **BASIC**. The

orbit tab displays all the parameters defining this orbit. However the HEO90 orbit is a duplicate of the **HEO270**. Observe the effects when you change the argument of perigee.

21. Change the Argument of Perigee value to 90 degrees.

22. Select **APPLY** and **OK**.

23. Toggle to the **VO** map.

24. 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.

25. Select **PAUSE**.

26. 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.

27. View as often as needed. When complete, select the **PAUSE** button. Close out according to the instructions in **STARTING AND USING SATELLITE TOOL KIT.**
Do not save this file.

Here are some additional STK activities.

Activity Five

TerraServer Directions

Before you begin you will need:
1. The basic version of STK loaded on your computer
2. An Internet connection
3. The ability to save and open a bitmap

TerraServer is a combined project of the U.S. Geological Survey and the Microsoft Corporation. Almost all of the U.S. has been mapped with aerial photographs and topographical imagery. Someday there will be high-resolution satellite images as well. TerraServer allows even remote areas to be downloaded into STK easily in the form of bitmaps. To download a TerraServer map into STK, simply follow these steps:

1. Get images and coordinates from the TerraServer website
2. Import them to a STK map
3. Repeat for higher resolution and topographical maps

Easy isn't it! Well, let's walk through it in case you need a little more help. First go to *www.terraserver-usa.com*. Click on **Advanced Find** and then select the **Place Link**. Enter your **home city** to see the aerial photo or topographical map. If your town doesn't come up, don't worry. Just pick another close city. Yours is there, but at this point, all we want is to learn to download the map. Once you have learned how to download maps, you can try different ways of finding them. Now click **Aerial Photo** and choose the last bar (**64 meter resolution**). Select **Larger** in the drop down menu, click **Print** in the upper right corner, change to **11x17 Print Size**, change to **Landscape**, and click **Show Gridlines**. Then select **Download** in the upper right corner and follow the directions given. **Don't close the window**! You will need to look back as you load the map into STK.

In STK, click the **Map Graphics Properties** in the map window. Do this by **highlighting your 2D map and then selecting Map Properties** (found on the toolbar). Select the **Images** Tab and click the **Add** button to select the correct image. Change the **scale** to match the **LLA bounds** in the window. Click **Change** and then **OK** to accept the new scale. You may repeat this process for multiple images. If you have an image of a large area and wish to layer the pictures, you must have the biggest image first on the image list. Although it takes longer, you will get a better picture if you piece together small, high-resolution portions instead of a single large image. This is because the earth is elliptical and big pictures will be distorted on a flat map.

Activity Six

Search and Rescue Directions

The first thing you should understand about Search and Rescue in STK is that it uses a **geodetic system** (a geodetic system is a latitude, longitude, and altitude (LLA) system that represents the elliptical nature of the earth). For this to make sense, you must realize that the earth is not flat or round, it's curved! Geodetic can be confusing and hard to work with in the small areas of most search and rescue missions, but we won't do anything too hard. If you don't remember how to download a map from Terraserver, reference the last section as we go along.

First, download a map in an area of interest or use a map you already have. Once you have loaded it into the program, create an aircraft by selecting the **Aircraft** icon in the drop down menu of **new items** found in the upper left hand corner of the tool bar. A Satellite may be visible on the tool bar, so you need to click on the **small triangle** next to it to see the aircraft. Once added, **right click on the Aircraft** icon in the **Objects Browse**r and click **Properties**. Expand the window so you can see and check the box labeled **"Clicking on map changes current point"**. You may also need to input the first set of latitude and longitude before you can click on the map. Do this by clicking **Insert Point** and typing the coordinates from some part of your downloaded image. Make sure you verify the "**+**" and "**-**"in the numbers or your aircraft will be on the wrong side of the globe.

Zoom into your loaded map by clicking the "**+**" **Magnifying Glass** in the toolbar and **click and drag a box over the area of your map**. This should allow you to zoom in enough to see your map. Continue the process until you have reached the desired level of magnification. Right click on the **Aircraft** and select the **Properties Browser**. Under **Basic**, select **Route** and click **Insert Point** for as many points as you wish to incorporate. Then click somewhere on the map in your **2D Graphics Window.** This should position the Aircraft on the map (if it's not already there). Continue to click for new points until you have created a search grid of your choosing on the map.

Next you will need to add a **Sensor** to your air-

craft by **highlighting the Aircraft** in the **Object Browser** and selecting a new **Sensor** from the same dropdown menu as the Aircraft. Now you may create a view area for your Sensor. To do this, simply right click on the **Sensor** and choose Properties Browser. Once there, verify that "**Simple Conic**" is selected as your Sensor type and **15 degrees** as your **view cone**. Close the properties page and right click on the **Sensor** again. Go to **Sensor Tools** and select **Access** to indicate when you find the **Targe**t. In the **Properties Browser** for the **Sensor**, scroll down to **Constraints**, select **Basic**, and limit the range to 2 kilometers. Allow the **Pointing** (found at the top of the list under Basic) to be **targeted** instead of **fixed.**

Make a Target somewhere on your map. To do this, simply **create it** as you have the Aircraft and Sensor. You will need to input its location in its **Properties Browser**. It can be hidden or unhidden at this point. Now have your search aircraft fly a grid over the area and look for the **Target** to be visible to the **Aircraft**. Next **rewind the scenario** back to the beginning and add a **Ground Vehicle** the same way you did the Aircraft. Add a **Sensor** with a 1- kilometer range to the **Ground Vehicle**. Have it drive down roads on the map (you can click on the map like you did for the aircraft to pick a new point). After you have finished a search with one Aircraft and Ground Vehicle, add multiple air and ground units. Try to have as little overlap as possible as you search while not missing a part of the search area. Remember to experiment with the program. Try different things to learn what it can do. This may be the free version, but anything you learn here can easily transfer to the full CAP version.

Activity Seven

Before you begin: STK Free Version should be installed on your computer. Close other programs on your computer to help it run faster.

Consider looking at the orbit descriptions in *Module 6 of Aerospace Dimensions* and Chapter 23 of *Aerospace: The Journey of Flight.*

In this section, we will learn how to create a satellite in STK and have that satellite orbit in each of the eight options given. Open the program and select a new scenario by clicking on the New Scenario button found in the upper left hand corner of the tool bar (it looks like a mountain with the sun rising over it). Select a new satellite by clicking on the Satellite symbol found in the dropdown window. The Satellite should be the picture already shown on the toolbar. This will open the **Orbit Wizard**, which will give you several options including what type of orbit you would like to create. Start by selecting Molniya (Note that a description of the satellite orbit selected is given). Continue clicking **Next** until you are out of the Orbit Wizard. Although you may change the numbers you are passing through, wait until you have seen what each orbit should look like before you change its characteristics.

You should see a ground trace area on your **2D Graphics Window**. Press the Play button (it works like a normal VCR) to set the animation in motion. Any other options will be provided just as they would on a normal VCR. After you have examined the ground trace of the orbit in your 2D window, remove the satellite by right-clicking on the **Satellite** icon in the **Object Browser** and pressing **Delete.** Repeat this process for each of the eight orbital patterns until you have an idea of what each one does and looks like. After you have created each of the satellites once, feel free to go back and experiment with the numbers that were preset in the Orbital Wizard and to create more than one satellite at a time.

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