STK Level 1 and Level 2 Training Manual

STK VERSION 12.7, JULY, 2023

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Level 1 - Beginner Training

STK Level 1 - Beginner training is designed to familiarize first-time users with STK workflow and provide a basic understanding of STK software capabilities. This training is designed to enable you to model and incorporate your own systems and missions throughout the lessons.

Evaluation license

This training covers the basics of STK that can be completed with an Evaluation license.

The Level 1 - Beginner training is a series of tutorials designed to get you started using STK.

Once you have completed these tutorials, you will be ready to take the free Level 1 STK Certification test! Visit www.agi.com/training-and-certification#cert/.

Tutorial	Capabilities
Lesson One: Build Scenarios (Design Reference Missions (DRM)) Learn how to create a scenario in STK.	STK Pro
Lesson Two: Objects and Properties Learn how to add and modify STK objects to a scenario.	STK Pro
Lesson Three: Access Report and Graphs Learn how to compute access between objects and generate reports on scenario data.	STK Pro
Lesson Four: Movies and Visual Data Files Learn how to make a movie in STK.	STK Pro
Lesson Five: Introduction to Connect Learn how to send Connect Commands in STK.	STK Pro

Note: For the STK 10 version of this training, visit http://help.agi.com/StartTraining/StartTraining1013.htm

Part 1: Build Scenarios (Design Reference Missions (DRM))

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro

Problem statement

Engineers and operators need an environment to quickly model and simulate their missions both analytically and visually.

Solution

Systems Tool Kit (STK) provides a physics-based simulation environment for digital mission engineering. Your system and component models can interact in STK, enabling you to measure their performance in the context of the complete mission. The NASA Systems Engineering Handbook (see the reference below) refers to this process in chapter four (4) as creating Design Reference Missions (DRMs) to capture the intended concept of operations (ConOps). This approach supports collaboration with distributed, multidisciplinary teams across all of your operational domains and life cycle phases. STK scenarios function as DRMs, and STK was deliberately built to design and evaluate these DRMs quickly. For many missions, two or more DRMs make up a single

ConOps. The design and performance analysis leading to the requirements should satisfy all of the DRMs. For more information on DRMs, you can check out AGI's webinar on Design Reference Missions.

> **Reference:** You can access the NASA Systems Engineering Handbook.

What you will learn

To begin using STK, you need a basic understanding of the STK workflow and layout. You will learn how to:

- Set up a new scenario
- Understand the STK windows
- Understand common tools

Video guidance

Set up a new STK scenario

In this section, you will learn to choose a central body for your scenario, create a new scenario, and then save your scenario.

Create a new scenario

First, you must create a new STK scenario; then you can build from there.

1. Launch STK (STK).

2. Click Create a Scenario in the Welcome to STK dialog box.

3. Use the STK: New Scenario Wizard to enter the scenario definition information specified in the following subsections.

Changing the central body

If enabled, the Central Body drop-down menu appears in the STK: New Scenario Window. Select from the list of planets to designate the scenario's primary central body. Earth is STK's default primary central body. To enable Planetary Options:

1. Launch STK (STK).

2. Extend the View menu when STK opens.

3. Click Planetary Options so that a check mark appears next to it. This enables the Central Body option on the STK: New Scenario Wizard.

Create a new scenario

Create a new STK Scenario () object using the STK: New Scenario Wizard tool. The Scenario object defines the context in which the properties and behavior of other objects are defined.

> **Note:** For additional information about this tool, visit the New Scenario Wizard help page at help.agi.com.

1. Click Create a Scenario in the Welcome to STK dialog box.

2. You can use the Central Body: selection, which defaults to Earth, to change the scenario's central body.

3. Enter the following in the STK: New Scenario Wizard:

Option	Description

Name	STK_NewScenario
Description	This is my first STK scenario.
Location	STK Default Directory (e.g., C:\Users\username\Documents\12). *This is the default directory, where the directory, scenario, and associated files are located when you save the scenario. You can choose a different directory or create a new directory by clicking the ellipsis (...) button.*
Start	Default Start Time *The default times are based on the date, time, and time zone set on your computer. The times are in Gregorian Coordinated Universal Time (also called UTCG or ZULU time).*
Stop	+ 24 hrs

Note: The default times are based on the date, time, and time zone set on your computer. For instance, if you are opening a scenario on 1 January 2023 and your computer is set to Eastern Time (US & Canada), the analysis Start time defaults to 1 Jan 2023 16:00:00.000 UTCG. UTCG is the Gregorian Coordinated Universal Time , or ZULU time. Since your computer is using Eastern Time, 1 Jan 2023 16:00:00.000 UTCG is equivalent to 1 Jan 2023 12:00:00.000 LCLG. LCLG is Gregorian Local Time or twelve noon.

Note: There are other analysis period options available by clicking the drop-down arrow. You can:

- Set the Start and Stop times to Today, the current date at 12:00 midnight based on your computer's internal clock
- Set the Start and Stop times to Tomorrow, the next day's date at 12:00 midnight based on your computer's internal clock
- Select from a calendar interface for the desired date
- Change the date and time formats

4. Click **OK** when you finish.

Saving the scenario

When the scenario first opens or when you complete a set of steps, you should Save (💾) the scenario.

1. Click Save (💾) when the scenario loads. STK creates a folder with the same name as your scenario for you.
2. Verify the scenario name and location in the Save As window.
3. Click **Save** .
4. Click **Close** in the Insert STK Objects tool. You will learn more about STK Objects tool in **Lesson 2: Objects and Properties**.

> **Note:** Save often during this lesson!

The STK workspace

The STK workspace offers many ways for you to organize and interact with its many varied windows. At the completion of this tutorial, practice workspace customization. Instructions are on the Managing Your STK Workspace Help page help.agi.com/stk/#gettingstarted/GetStart_ToolbarsAndDocking.htm.

> **Note:** All windows and toolbars discussed in this lesson are some of the most commonly used defaults you see when you install and open STK for the first time STK.

Menus and tools

Menus and toolbars are at the top of STK. This tutorial covers selected tools. Tools not covered in this tutorial are covered in later lessons. You can display or hide toolbars to customize your STK windows. For extensive information on using STK Toolbars, go to the Using STK Toolbars Help page.

1. Extend the View menu.
2. Hover over Toolbars to extend the menu. This is one way to choose the toolbars you require.
3. Right-click in the empty space to the right of the currently available toolbars. This is another way to quickly enable and disable Menu selections and toolbars.

Object Browser

When you introduce an object into a scenario, it appears in the Object Browser. You can see the Scenario ( ) object (STK_NewScenario) you created. As you create more objects, they appear in the Object Browser in a parent-child relationship. For more information on the Object Browser, go to the Getting started with the Object Browser Help page.

Understanding the STK Graphics windows

The 2D and 3D Graphics windows graphically display information about your scenario. By default, the 2D and 3D Graphics Windows are in the Integrated Workspace. They can be evenly spaced in that area, as well as minimized, maximized, or closed. STK organizes the integrated windows with tabs at the bottom of the Integrated Workspace.

1. Extend the Window menu.
2. Select Tile Vertically to evenly space the windows side-by-side in the workspace.

Understanding the 2D Graphics window

The 2D Graphics window graphically displays information about your scenario. Although not as exciting as the 3D Graphics window, the 2D Graphics window gives you one giant advantage: you can see the whole central body at one glance. For more detailed information about the 2D Graphics window, click the 2D Graphics Window Help page.

Properties

You can customize the 2D Graphics Window by modifying its properties, such as colors, geographic features, display formats, and latitude / longitude line spacing. Look at the 2D Graphics window and notice the separation between umbra and direct sun. You can specify this separation in the 2D Graphics Window's Properties:

1. Click Properties () in the 2D Graphics Defaults toolbar.
2. Select the Lighting page.
3. Notice that Day and Night are enabled by default in the Shading section.
4. Click **Cancel** to close the Properties window.

Grab Globe

When activated, Grab Globe enables you to move or pan the central body in grab mode. Grab Globe is enabled by default.

1. Click Grab Globe () in the 2D Graphics Defaults toolbar if it's not enabled.
2. To pan, place your cursor on the 2D Graphics window map.
3. Hold the left mouse button and drag the mouse around the 2D Graphics window.

Mouse scroll wheel

You can zoom in and zoom out using the mouse scroll wheel. Using the mouse scroll wheel does not add any zoom levels to the zoom stack, so after zooming in using the mouse scroll wheel, hitting Zoom Out zooms all the way out to a global view.

1. Place your cursor on the 2D Graphics window map.
2. Move the mouse scroll wheel up to zoom in on the 2D Graphics window map.

3. Move the mouse scroll wheel down to zoom out on the 2D Graphics window map.

2D Graphics toolbar

The 2D Graphics toolbar provides easy access to the most frequently used options and tools to control the graphical display of your scenario in the 2D Graphics window.

Measure Tool

The Measure tool measures the shortest distance between two points and reports the azimuth bearing.

1. Click Measure ( ) in the 2D Graphics toolbar.
2. Place your cursor on the 2D Graphics window map.
3. Hold down the left mouse button and drag the cursor to another spot on the map.
4. Release the left mouse button. The distance between the two points and the azimuth bearing display in the lower left-hand corner of the Status Bar and in the Message Viewer.

> **Note:** The data is only as good as where you clicked on the map. In general, this tool is a good way to get an approximate distance measurement between two points. If you require exact distances, you will need to measure the distance between two STK objects using the Report & Graph Manager.

Understanding the 3D Graphics window

STK enables you to view complex information in a 3D Graphics window. You can observe relationships among space, air, land, and sea objects as they exist in the present as well as in the past and future. Like you did with the 2D Graphics window, you'll practice using selected tools. For detailed information about the 3D Graphics window, click 3D Graphics Window Help page.

Using the Mouse

In addition to tools available in toolbars, the 3D Graphics window has additional mouse controls that manipulate the 3D Graphics window. Get familiar with the mouse controls.

1. Double-click the left mouse button on any spot on the globe to display the latitude and longitude of the selected spot.
2. Place your cursor on the 3D Graphics window globe.
3. Hold down the left mouse button and move the mouse around to rotate the globe.
4. In one motion, hold down the right mouse button and push the mouse away from you to Zoom out.
5. While holding down the right mouse button, pull the mouse closer to you to Zoom in.
6. Hold down the Shift key and left mouse button while moving the mouse around. This will pan and tilt the virtual camera.
7. After you pan and tilt in the previous step, release the Shift key and left mouse button.
8. Hold the left mouse button down and move the mouse around to keep the camera in a fixed point in space and change its orientation.

3D Graphics toolbar

The 3D Graphics toolbar provides easy access to the most frequently used options and tools used to control the graphical display of your scenario in the 3D visualization windows. You will focus on the Home View, Flashlight, and 3D Measure tools, but you can see descriptions of all the tools on the 3D Graphics Toolbars Help page.

Home View

Home View displays the default view. If you are lost in your view, this is one of your best friends. It will bring you back to your home view with one click.

1. Use the scroll wheel to zoom in close to the surface of the central body (Earth).
2. Click Home View ( ) in the 3D Graphics toolbar to reorient the 3D Graphics camera back on the default Earth-centered view.

3D Measure tool

Similar to the 2D Measure tool, the 3D Measure tool measures the shortest distance between two points and the azimuth bearing in the 3D Graphics window.

1. Click 3D Measure ( ) in the 3D Graphics toolbar.
2. Place your cursor on the 3D Graphics window map.
3. Hold down the left mouse button and drag the cursor to another spot on the map.
4. Release the left mouse button. The distance between the two points and the azimuth bearing display in the lower left hand corner of the Status Bar and the Message Viewer.

> **Note:** Remember, the data is only as good as where you clicked on the map. In general, this tool is a good way to get an approximate distance between two points. If you require exact distances, you will need to measure the distance between two STK objects using the Report & Graph Manager. You can learn more about reports and graphs in Lesson 3: Access Reports and Graphs.

Terrain Server

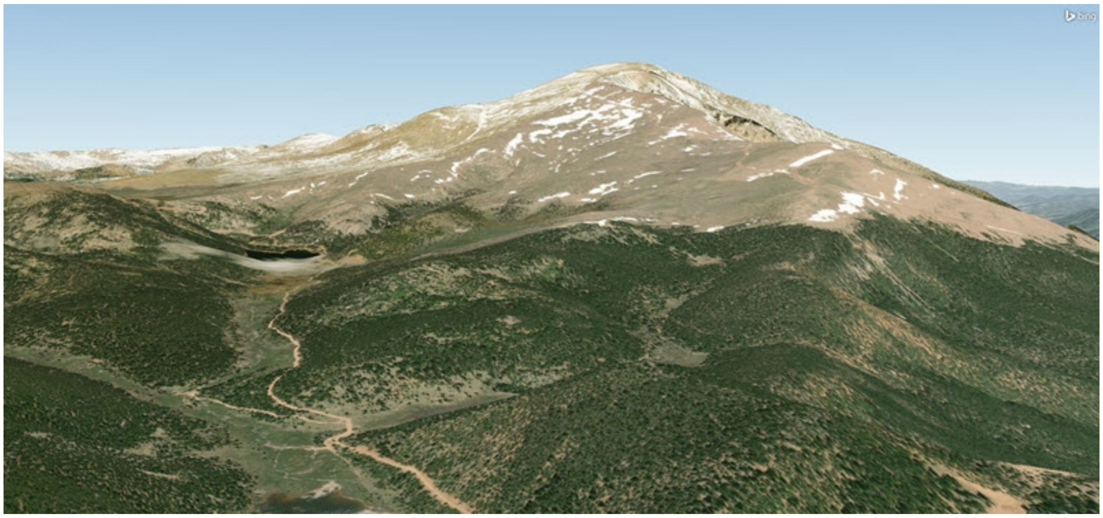
The Terrain Server distributes Earth terrain data for visualization or analysis. By default, STK connects to the AGI Terrain Server, which is available via an internet connection to all STK users.

1. Check your internet connection via your status bar. If online operations are available ( ), continue to the next step. If online operations are not available ( ), skip to the next section.
2. Zoom In ( ) on an area of interest in the 3D Graphics window.

3. Use the mouse scroll wheel to zoom very close to the Earth's surface.

4. Hold down the left mouse button and push the mouse away from you to tilt the globe on its side.

   You should see terrain features. If you happen to be zoomed into a flat area, readjust your area to a more hilly or mountainous location. If you find yourself under the terrain, zoom out a bit and readjust your view.



TERRAIN SERVER STREAMING TERRAIN

Animation toolbar

The animation tool bar helps you control the progression of your scenario. With a few clicks, you can control the start time, stop time, and how quickly the scenario progresses from start to stop. Use the animation controls to play through the scenario.

1. Select the Window menu.
2. Select Tile Vertically.
3. Click Home View ( ) in the 3D Graphics toolbar.
4. In the Animation toolbar, click Start ( ) to have the scenario animate forward in time from the current point.
5. Click Pause ( ) to stop the scenario animation.

6. Click Step Forward () or Step Backward () to progress one step at a time through the scenario.

7. Click Reverse ( ) to have the scenario animation rewind from the current point.

8. Experiment with increasing () and decreasing () the speed of the animation, which by default is 10 seconds. This will also affect the time step of Step Forward and Step Backward as well.

9. At any point, click Reset () to have the scenario return to the start time. This does not reset the speed of the animation.

   Besides the buttons that increase and decrease animation speed, you can set a scenario to run at a particular speed using the following yellow clock symbols:

   - **Normal Animation Mode** (): The scenario animates in accordance with the scenario time you defined when creating the scenario and the defined time steps. Again, by default, the defined time steps are 10 seconds.
   - **Real-Time Animation Mode** (): The scenario animates in real time in accordance with your computer's internal clock.
   - **X Real-Time Animation Mode** (): The scenario sets the playback to a sped-up or slowed-down version of real time. For instance, entering a value of 1 will have the scenario run at real time. Entering a value greater than 1 speeds up the animation. A value between 0 and 1 will slow down the animation.

Timeline View

Use Timeline View to visualize a variety of time intervals within your scenario. The user interface of the Timeline View is comprised of a toolbar, three timelines, and rows of time components.

Time Display

The Time Display is the largest and most granular of the timelines. Use the gray pointer to adjust the animation time to any point within the Time Display's current boundary to visualize time events.

1. Click Home View ( ) in the 3D Graphics toolbar to rest the view.
2. Click Zoom Out ( ) in the 2D Graphics Defaults toolbar to zoom out of the 2D window. Click Zoom Out ( ) as many times as needed until the 2D map fills the display window.
3. While looking at the 2D Graphics or 3D Graphics window, put your cursor on the Gray Pointer ( ) in the Timeline View.
4. Hold down the left mouse button and slide the Gray Pointer to the right.
5. Notice the globe rotating and the day-night shading on the 2D Graphics window moving as you scroll through the scenario time period.
6. Click Save ( ).

Summary

You got a thorough introduction of the STK: New Scenario Wizard and a brief outline of STK tools and windows such as the Object Browser and the Timeline View. The bulk of the information in this tutorial helped you to become familiar with the functions and tools of the 2D and 3D Graphics windows. These windows are important for your situational awareness while using STK.

Part 2: Objects and Properties

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro

Problem statement

Engineers and operators need to quickly add realistic analytical and visual properties to objects in STK. They may need a realistic satellite attitude, analysis of an enclosed area in a deep canyon, a mission plan for an aircraft flight route, a sensor footprint, or a briefing with detailed visuals and analysis.

Solution

Use STK to insert **STK objects** into your scenario. Then update the object's **properties** to define its characteristics relevant to your scenario.

What you will learn

Upon completion of this tutorial, you will be able to:

- Update STK's Databases
- Insert objects into your STK scenario
- Modify properties
- Understand why you are using different objects in your analysis

Note: There are many objects and properties used in STK. Not all objects or properties are covered in this lesson. Other tutorials cover some objects or properties not discussed in this tutorial.

Video guidance

Data Update Utility

If you have an internet connection, you can use the Data Update Utility to update astro datasets (such as EOP, Space Weather, Leap Second, time.ker, Solar Flux, satellite databases, GPS, etc). You can manually update one or more data sets or you can you can schedule a time and frequency for automatic updates.

If you work with satellites, update your databases prior to opening a new scenario.

1. Launch STK ().
2. Extend the Utilities menu.
3. Select the Data Update... option.

   Note: The color of the data set indicates its current status: red data sets have updates available, black are up to date, and purple are not currently available on AGI servers (these are rarely seen). If you select the Enable Automatic Updates check box, you can set your preferred options. Your PC needs to be on and connected to the Internet for the auto updates to occur.

4. Select all the data set check boxes that have updates available (Red) in the Update Column. Ignore black and purple data sets.
5. Click **Update Now** .
6. Click **Yes** when the warning appears.
7. Wait for the progress bar in the lower right-hand corner of the tool to complete and for all the data sets to turn black.
8. Click **OK** when the update is complete to close the Data Update Utility.
9. Click ✕ **Exit STK** in the Welcome to STK dialog box.

Create the new scenario

Create a new scenario using the following properties. For a step-by-step guide to creating a new scenario, see **Lesson One: Build Scenarios**.

1. Launch STK ( ).
2. Click **Create a Scenario** in the Welcome to STK dialog box.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	STK_Objects_Properties
Location:	Default
Start:	Default
Stop:	Default

4. Click **OK** when you finish.
5. Click Save ( ) when the scenario loads. STK creates a folder with the same name as your scenario for you.

6. Verify the scenario name and location in the Save As window.

7. Click **Save** .

Modifying the Scenario object's properties

The Scenario () object defines the context that influences the properties and behavior of other objects.

1. Right-click STK_Objects_Properties () in the Object Browser.

2. Select Properties ().

When the Scenario () object's properties open, there is a branching list on the left containing pages of properties. The main category that you will need to know is the Basic category, which holds properties such as Time, Units, Database, and many others.

Basic Time

In the Basic - Time page, the Analysis Period defines the epoch and the start/stop times for your scenario. Animation properties control the animation cycle, step duration, and the intervals between refresh updates in the graphics windows.

> **Note:** Throughout the various STK tutorials, you are instructed to browse to a properties page. Just click the specified page on the left.

Basic Units

Scenario Units establish the default settings for all units of measure used in a scenario.

1. Select the Basic - Units page.

2. Change the unit of any dimension listed in the table, click the CurrentUnit (e.g., Kilometers (km)) and select the appropriate value from the shortcut menu.

Basic Database

Database properties enable you to set the defaults for the city, facility, satellite, and star databases. You can specify a stock STK database or one of your own that meets STK's format requirements.

Basic Terrain

You can use the **Terrain properties** page of a scenario to enable streaming terrain that enables you to view terrain features in the 3D Graphics window.

> **Note:** To use analytical terrain in your scenario requires STK PRO.

1. Select the Basic - Terrain page.

2. Take a look around the Terrain page.

In the Terrain page, you should see the "Use terrain server for analysis" option. You can toggle the Terrain Server on and off with this option. "Advanced Analysis Operations" and "Custom Analysis Terrain Sources" require an STK Professional license.

Basic 3D Tiles

STK 12 adds the ability to include 3DTileset geometry (e.g., massive city models, photogrammetry, etc) computationally in your analysis. The constraint 3DTiles Mask is available for Facility, Target, and Place objects, as well as all vehicle types. This allows for 3D Tileset geometry to obstruct visibility when computing access. You can use a 3D Titleset hosted in GCS, Cesium ion, or from the local file system for analysis with this constraint. Requires the STK Professional license.

Description

The Description page for an object is a handy place to record miscellaneous information about the object and its role in your analytical or operational task. By selecting this property, you should see a text box for a "Short Description," a larger text box for a "Long Description," and an area to add "Metadata."

Option	Description
Surface Reference of Earth Globes	Use either Mean Sea Level or WGS84 Ellipsoid (default).
3D Object Editing	Allows you to pull great arc vehicles, facilities, and targets below the globe's surface reference - thus assigning them negative altitude values - while using 3D object editing.
Image Cache	Temporarily stores imagery for the globe. You may need to increase the size of the cache if all of the images that you are trying to display cannot be loaded at the same time or if an image appears blurry.
Terrain Cache	Temporarily stores terrain data for the globe. You may need to increase the size of the cache if all of the terrain that you are trying to display cannot be loaded at the same time or if the globe surface at the terrain level appears blurry.
Surface Lines	Allows you to select an option for displaying lines on the surface of the central body when terrain data is available. Select **When Terrain Server is on** to display surface lines on terrain only when you are connected to a terrain server, **On** to display surface lines on terrain data whenever it is available from any source, or **Off** to never display surface lines on terrain.

Insert STK Objects tool

The Insert STK Objects tool provides an easy, convenient way to populate a scenario. The Insert STK Objects tool, by default, displays the most commonly-used scenario objects. You can customize the tool to display all the scenario objects or a user-defined subset of objects.

1. Click **Close** on the Insert STK Objects tool.

   There are two ways to reopen the Insert STK Objects tool:

   - Click Insert Object ( ) located in the Default toolbar.
   - Expand the Insert menu and select New.

2. Reopen the Insert STK Objects tool by using one of the aforementioned methods.

Objects and Methods

In the Insert STK Objects tool, you will see Scenario Objects, Attached Objects, and Methods. Scenario objects are children of the larger Scenario ( ) (e.g. STK_Objects_Properties). Attached objects are the children of scenario objects. You must add scenario objects before you can add attached objects.

To insert an object, you must choose a particular method. These methods determine the starting properties of each object and you can change these properties later. For instance, when this training says to "Insert a Default Object," that means insert an object using the default method. You should pick the method for the demands of your scenario, as we will show later in this training.

For instance, you could insert an Aircraft ( ) object (a Scenario object) using the Insert Default ( ) method. Then, you could insert a Sensor ( ) object (an Attached object) onto that aircraft.

Satellite object

The Satellite object models the properties and behavior of a vehicle in orbit around a central body.

From Standard Object Database

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the From Standard Object Database ( ) method.

> **Note:** Both the satellite database file and the corresponding TLE file evolve over time and need to be updated as needed.

The U.S. Strategic Command (USSTRATCOM) currently keeps track of thousands of space objects. These objects constitute the space object catalog. While most of the catalog is made available to the public, some information is restricted. AGI provides the publicly released information for use with STK in the form of satellite database files and two-line mean element files (TLEs).

3. Click **Insert...** .
4. In the Name or ID: field, enter 25544 (the SSC number or Satellite Catalog Number)
5. Click **Search** .
6. In the Results: field, select ISS (Zarya).
7. Click **Insert** .

The ISS (Zarya) is downloaded from AGI's Standard Object Data Service. If you were to choose ISS or Zarya using Local Database, you would need to ensure you've updated your satellite database.

8. Click **Close** to close the Search Standard Object Data window.

View in 2D

1. Bring the 2D Graphics window to the front.
2. Zoom Out ( ) if needed to see the entire earth and the current orbit track of ISS_ZARYA_25544 ( ).

INTERNATIONAL SPACE STATION ORBIT IN 2D

3. Using the Animation Toolbar, make any adjustments to the time step.

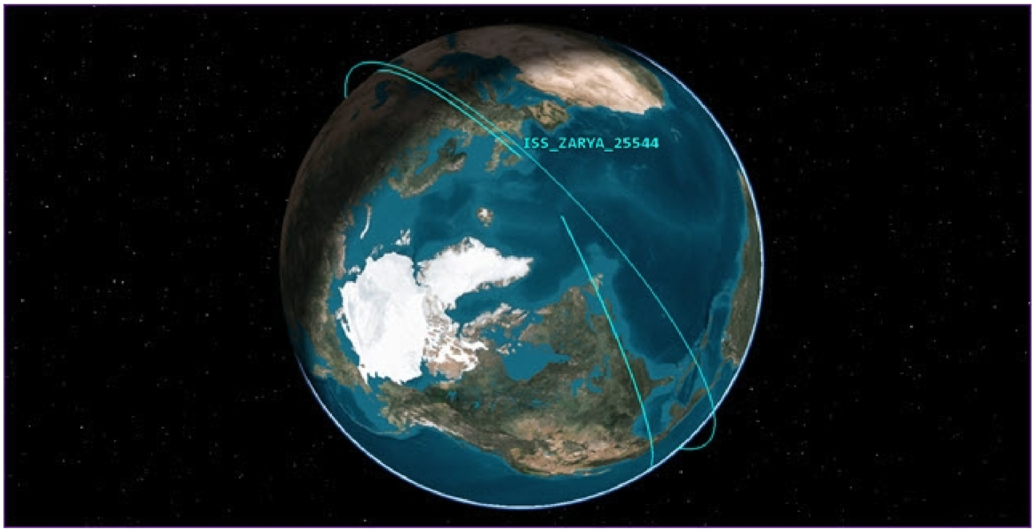
4. Click Start ( ) to animate the scenario.

5. When finished, click Reset ().

View in 3D

1. Bring the 3D Graphics window to the front.

2. Click Home View ().



INTERNATIONAL SPACE STATION ORBIT IN 3D

In this view, you can see both a ground track representing the ISS's current orbit and the actual orbit track. Not all Satellite ( ) objects are represented by both a ground track and an orbit track.

3. Right-click on ISS_ZARYA_25544 ( ) in the Object Browser.
4. Select Zoom To.
5. Using the Animation Toolbar, make any adjustments to the time step.
6. Click Start ( ) to animate the scenario.
7. When finished, click Reset ( ).

Real-time Animation Mode

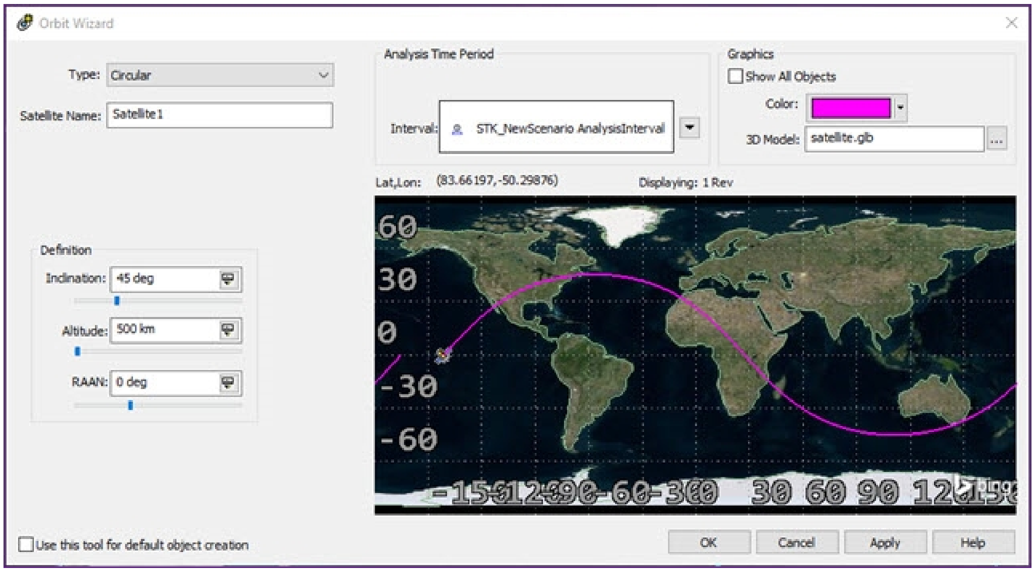
The scenario animates in real time in accordance with your computer's internal clock. In order for you to be able to visualize ISS_ZARYA_25544 ( ) using real-time animation mode, your scenario analysis period must fall within your current time. For instance, if the analysis period is set at 1 Jun 2020 18:00:00.000 UTCG - 2 Jun 2020 18:00:00.000 UTCG, and the actual local time is 1 Jun 2020 11:00 Mountain Time (11:00 am), ISS_ZARYA_25544 ( ) is not be visible. 1 Jun 2020 18:00:00.000 UTCG is 1 Jun 2020 12:00 local time. You'll have to adjust your scenario times if you experience this problem. If you do adjust your times, other moving objects such as the Aircraft ( ) object need to be readjusted too.

1. Ensure your scenario analysis period falls within your local time period.
2. In the Animation Toolbar, select Real-time Animation Mode ( ).
3. Click Start ( ). You're now visualizing ISS_ZARYA_25544 ( ) at its actual location based on the TLE from which it was propagated.
4. When finished, click Reset ( ).
5. In the Animation Toolbar, select Normal Animation Mode ( ).
6. Click Reset ( ).

Orbit Wizard

The **Orbit Wizard**Orbit Wizard is a satellite-level tool designed to assist you in creating any one of several standard orbits, or designing your own satellite orbit. The configurable options available depends on the orbit type selected.

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the Orbit Wizard ( ) method.
3. Click **Insert...** .



ORBIT WIZARD

4. When the Orbit Wizard opens, set the following:

Option	Value
Type:	Repeating Ground Trace
Satellite Name:	RGT_Sat
Approximate Altitude:	600 km

Note that the Analysis Time Period / Interval: defaults to your scenario analysis period. The satellite is propagated for that period.

5. Click OK .

6. Just like you did with ISS_ZARYA_25544 ( ), view RGT_Sat ( ) in the 2D Graphics and 3D Graphics windows.

7. Click Start ( ) to animate the scenario if desired.

8. When finished, click Reset ( ).

Unlike a Satellite ( ) object propagated using TLEs, a Satellite ( ) object propagated using the Orbit Wizard can be edited using your own data.

SATELLITE VECTORS AND ATTITUDE

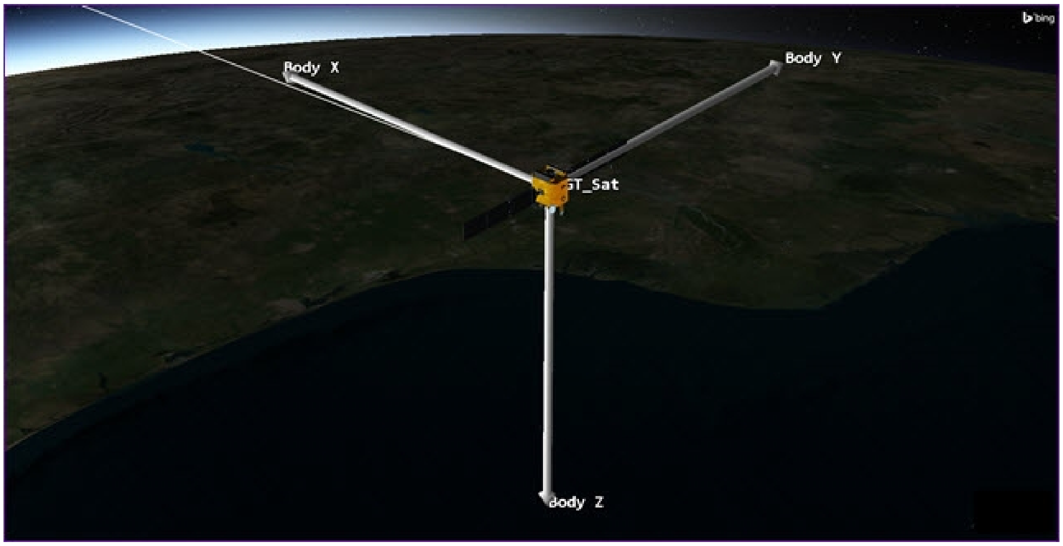
Sometimes you need to understand your attitude.

1. Return to RGT_Sat's ( ) properties ( ).
2. Select the 3D Graphics - Vector page.
3. Select the Axes tab.
4. Enable Body Axes Show option.
5. Change the Body Axes color if desired.

   If you double-click on the Color cell, you can change the color of Angles, Axes, Points, Vectors, or Planes. This presents a shortcut menu which, when clicked, shows a color palette. Simply click the color you want to apply to your geometric element.
6. Click Apply .

View in 3D

1. Right-click on RGT_Sat ( ) in the Object Browser.
2. Select Zoom To.
3. Bring the 3D Graphics window to the front.



NADIR ALIGNMENT WITH ECI VELOCITY CONSTRAINT

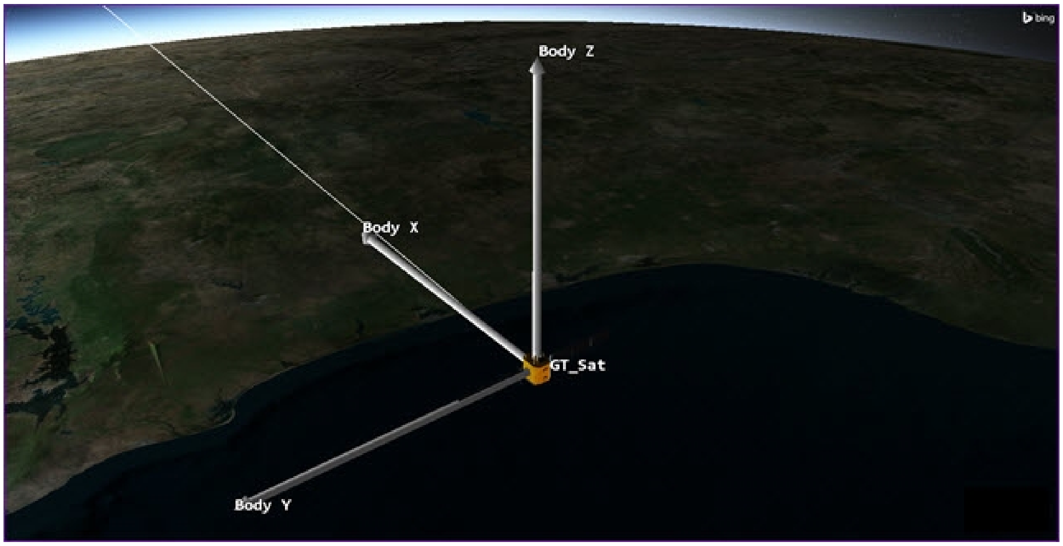
The Satellite ( ) object defaults to a Nadir alignment with ECI velocity constraint attitude. In this vehicle body frame definition, the vehicle's Z axis is aligned with the nadir direction and its X axis is constrained in the direction of the ECI velocity vector.

> **Note:** Satellite, Missile, Aircraft, Ship, and Ground Vehicle objects have one thing in common. The Body X is aligned with the direction of travel unless you change the attitude.

Attitude Profiles

Vehicle body frame definitions are based on Attitude profiles.

1. Return to RGT_Sat's ( ) properties ( ).
2. Select the Basic - Attitude page.
3. Change the Basic Type: to ECF Velocity Alignment with Radial Constraint.
4. Click Apply .
5. Bring the 3D Graphics window to the front.



ECF VELOCITY ALIGNMENT WITH RADIAL CONSTRAINT

The vehicle's X axis is aligned with the Earth-fixed velocity vector direction and the Z axis is constrained in the radial direction (the direction along the position vector and opposite to geocentric nadir).

Set the Nadir alignment back to ECI velocity constraint

1. Return to RGT_Sat's ( ) properties ( ) Basic - Attitude page.
2. Change the Basic Type: back to Nadir alignment with ECI velocity constraint
3. Click OK .

Update the Local Satellite Database

There are times when you need to look at older data or you want to use local files such as your own TLE file. In this section, we'll use an archived database. You must be connected to the Internet to utilize this source.

1. Open the STK_Objects_Properties's ( ) properties ( ).
2. Select the Basic - Database page.

3. Ensure Database Type: is set to Satellite.

4. Click **Update Database Files...**

Update Satellite Database (Requires Internet)

You can update satellite database information using Update Database Files.

Option	Description
Update Database	Obtains the latest satellite database information from the AGI satellite database server
Obtain Archived Database	Obtains an older version of the database from the date specified in the Archive Date field. If an archive is not available from the specified date, the archive for the next newest date is used instead.

1. Select the Obtain Archived Database option.

2. Select Specific Database: and ensure it's set to stkAllTLE (the entire database of satellites).

3. Click the Database ellipsis (...).

4. Select the scenario folder or place the file in a folder of your choice.

> **Note:** Your default save location may be in C:/ProgramData/... and this folder may be hidden. To unhide it, you must select the option in your File Explorer to show all hidden folders. Consult the help for Microsoft Windows to select that option.

5. Specify the Archive Date by entering it in the text field or using the drop-down menu. In the case, change the year to the previous year (e.g. if it's 2023, change it to 2022).

6. Click **Update** . If an archive is not available for the specified date, the archive for the next newest data is used instead.

7. When the Information window appears, click **OK** .

8. Click **Close** to exit the Update Satellite Database dialog box.

9. Click **OK** to accept your changes and to close the Properties Browser.

Insert a Satellite from the Local Satellite Database

Use the Insert From Satellite Database tool to query a locally installed Spacecraft database.

1. Insert a Satellite ( ) object using the From TLE File ( ) method.

2. Navigate to the archived satellite database file (e.g. C:\Users\username\Documents\STK 12\STK_Objects_Properties).

3. Select stkAllTLE.tce.

4. Click **Open** .

5. Click **Yes** when the Question window appears. Be patient, this can take a few minutes.

Satellite Database TLE Source

The Satellite Database TLE Source window specifies the satellite database TLE source.

1. Click **Modify...** on the Insert From Satellite Database dialog box.

2. Clear the On propagation, automatically retrieve elements check box in the Satellite Database: TLE Source dialog box. Disabling this option keeps the satellite's designated TLEs from being automatically updated next time you open the scenario.

3. Click **OK** to close the Satellite Database: TLE Source dialog box.

4. Click **Yes** when the Question window appears. Be patient, this can take a few minutes.

5. Enter 25544 in the SSC Number field.

6. Click **Search** .

7. Select Zarya.

8. Click **Insert** .

9. Click **Close** to close the Insert From Satellite Database dialog box.

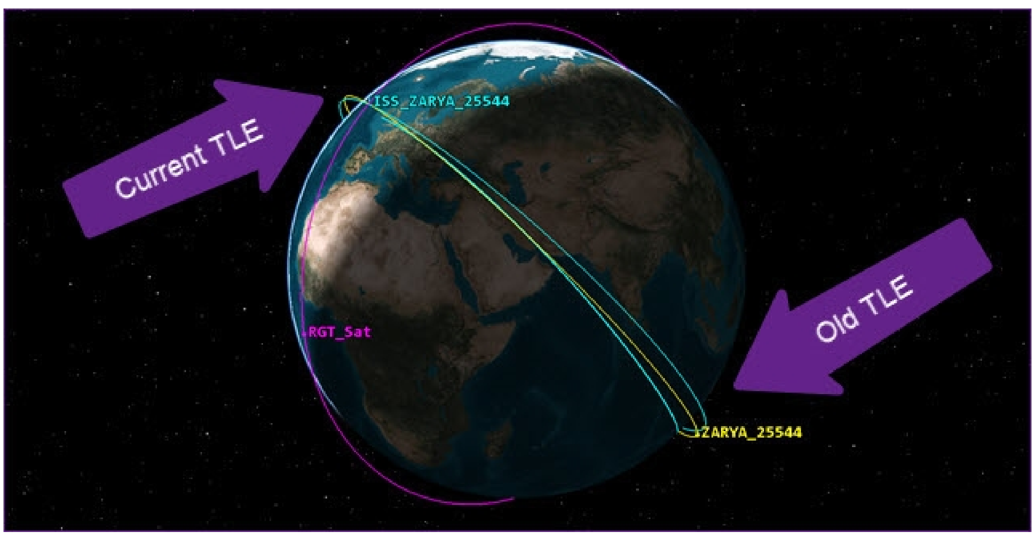
New Versus Old TLEs

Earlier you inserted ISS_ZARYA_25544 using the most current TLE. Now you've inserted the same satellite using an archived TLE that is a year old. STK propagated the TLE from a year ago. Any changes to the orbit during that period are not reflected. You should be able to see the difference in both the 2D and 3D Graphics windows.

1. Bring the 3D Graphics window to the front.

2. Click Home View ( ) on the 3D Graphics window toolbar.

3. Rearrange your view so that you can see both satellites.



NEW VERSUS OLD TLE DATA

You should see a difference between using old data and new data. This is a great example why you need to use current data or data that matches your analysis period.

4. When finished, clear the ZARYA_25544 check box in the Object Browser. This turns object off visually in both the 2D and 3D Graphics windows, but the object is still available analytically if needed.

Aircraft object

The Aircraft () object models the properties and behavior of a vehicle that travels in a great arc route, generally above the surface of the earth.

1. Insert an Aircraft () object using the Insert Default () method.

Renaming objects

It's usual to rename objects in STK. If you choose not to rename your objects, STK will name them giving each object a number. For instance, the first Aircraft () object that you insert will be named Aircraft1. The next Aircraft () object you insert will be named Aircraft2 and so on.

1. Right-click on Aircraft1 () in the Object Browser.
2. Select Rename in the shortcut menu.
3. Rename Aircraft1 () to My_Plane.

Properties

1. Open My_Plane's () properties ().
2. Select the Basic - Route page.

START TIME

The Start Time defaults to the scenario start time and you can reset it. The Stop Time field is read-only and is defined by the last waypoint for the vehicle.

1. Click the down arrow or right-click on the start or stop times to interact with the object time options.
2. Hover over Start Time.

The shortcut gives you an idea of other selections, such as: Set to Today or Set to Tomorrow. When you enter waypoints for the object, this window enables the Replace With Time option. If you change the Start Time after you enter waypoints, all time entries in the waypoint table are updated automatically.

ROUTE CALCULATION METHOD

You can use the Route Calculation Method shortcut menu to select the manner in which the route is calculated between each waypoint. For this training, use the default Smooth Rate method.

Option	Description
Specify Rate/Acc	Uses the Speed and Acceleration properties of each waypoint
Specify Time	Uses the Time properties of each waypoint. This is useful if you want an object to stay in one spot for a period of time without moving
Smooth Rate	Uses the Speed property of each waypoint

ALTITUDE REFERENCE

Ground vehicles, aircraft, and ships can reference their altitude from mean sea level, terrain data, or WGS84. The World Geodetic System 1984 (WGS 84) is a 3-dimensional coordinate reference frame for establishing latitude, longitude and heights for navigation, positioning and targeting for the DoD, IC, NATO, International Hydrographic Office and the International Civil Aviation Organization.

Since you're currently using Terrain Server, a good rule of thumb when creating an aircraft flight route using the Great Arc Propagator, is to set the altitude reference to Mean Sea Level. In the United States, mean sea level is defined as the mean height of the surface of the sea for all stages of the tide over a 19-year period.

1. Open the Reference: shortcut menu in the Altitude Reference frame.
2. Select MSL.

WAYPOINTS

The waypoints that comprise the great arc route are contained in a table that displays each point, along with all of its properties, in sequence. The table can be used to directly edit those properties. One row of values describes a single waypoint in the route of the vehicle.

There are two ways to enter waypoints:

- Clicking Insert Point and manually entering values.
- Clicking on the 2D Graphics window when the Basic - Route page is open.

Check out more information about the Great Arc Waypoint Properties by looking at the table with the same name on the **Great Arc Waypoint Properties** help page. It describes all the major position, movement, and time properties, along with the calculation method.

CLICKING ON MAP

1. Leave My_Plane's ( ) properties ( ) open.
2. Bring the 2D Graphics window to the front by clicking on the 2D Graphic tab below the Properties Browser.
3. Click somewhere in the Atlantic Ocean near the African coast and then click somewhere in the Indian Ocean near the Indian coast.

   > **Important:** Make sure you only click where you want a waypoint!

4. Bring My_Plane's ( ) properties ( ) back to the front.

   Notice that the Altitude, Speed, and Turn Radius values are copied for each waypoint.

MODIFY A WAYPOINT LOCATION

1. Select the first waypoint.
2. Select the Clicking on map changes current point check box.
3. Bring the 2D Graphics window back to the front.
4. Click somewhere in the Pacific Ocean near the United States coast.

Wherever you click, the waypoint will be moved to that location. Also, the Great Arc Propagator will automatically reroute the aircraft using the shortest distance between the waypoints. If you want to fly in a specific direction, you will need to add more waypoints.

5. Bring My_Plane's ( ) properties ( ) back to the front.
6. Click **Delete Point** until all waypoints are deleted.
7. Clear the Clicking on map changes current point check box.
8. Click **Apply** .

INSERT POINT

You can insert waypoints manually. This is more precise than clicking on the map.

1. Click **Insert Point** .
2. Enter the following by clicking in the associated cell. Press the Enter key on the keyboard after each entry:

Option	Value
Latitude	38.00 deg
Longitude	-120.00 deg

3. Click **Insert Point** .
4. Enter the following for the second waypoint:

Option	Value
Latitude	30.00 deg
Longitude	-99.00 deg

5. Click **Insert Point** .

6. Enter the following for the third waypoint:

Option	Value
Latitude	40.00 deg
Longitude	-77.00 deg

7. Click Apply .

View the waypoints in the 2D and 3D Graphics windows

My_Plane's ( ) flight route is located in the Continental United States.

1. Bring the 2D Graphics window to the front to view the flight route.
2. Bring the 3D Graphics window to the front to view the flight route.
3. Return to My_Plane's ( ) properties ( ).

MODIFY A WAYPOINT'S ALTITUDE

When modifying one waypoint, you need to know proper units. For instance, look at the first waypoint:

- The Altitude unit uses km (kilometers).
- The Speed unit uses km/sec (kilometers per second).
- The Turn Radius unit uses km.

  Modify the first waypoint's altitude to 20000 ft (feet).

1. Select the first waypoint.
2. Click inside the Altitude cell.
3. Enter 20000 ft.
4. Press Enter on the keyboard.

Notice the unit reverts back to the default km. My_Plane ( ) is flying at an altitude of 6.09600000 km (20000 ft) at the first waypoint. It slowly ascends until it reaches the second waypoint.

MODIFY A WAYPOINT'S SPEED

Modify the first waypoint's speed to 450 mi/hr (miles per hour).

1. Click inside the Speed cell.
2. Enter 450 mi/hr.
3. Press Enter on the keyboard.

My_Plane slowly decelerates between the first and second waypoints. You can see this in the Accel cell.

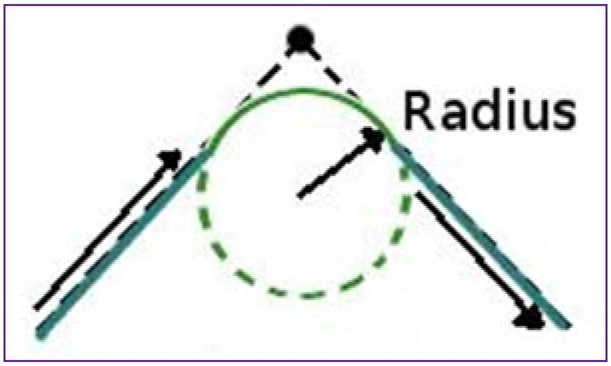
MODIFY A WAYPOINT'S TURN RADIUS

Modify the first waypoint's turn radius to two (2) km.

1. Click inside the Turn Radius cell.
2. Enter 2 km.
3. Press Enter on the keyboard.
4. Click Apply .

The great arc path will never reach the given waypoint unless the change in heading is negligible. Instead, the turn will be inscribed between the lines connecting the previous procedure to the given waypoint and the waypoint to the next procedure. The position will arrive along the line from the previous procedure toward the given waypoint and leave along the line from the given waypoint toward the next procedure. The radius of the inscribed turn will be contained to the vehicle's radius. See the figure below for a visual representation of this.

> **Note:** Keep this in mind when creating a movie. If your aircraft isn't flying over the location you clicked on the map or entered as a latitude and longitude, you should either decrease the turn radius or modify the waypoint location.



TURN RADIUS

SET ALL GRID VALUES TOOL

With the Set All Grid Values tool, you can modify the Altitude, Speed, Acceleration, and Turn Radius properties for all waypoints that are currently defined in the table. The properties that can be modified using this tool will be constrained with respect to the currently selected Route Calculation Method.

1. Click Set All... .
2. Select Altitude, Speed, and Turn Radius in the Set All Grid Values dialog box.

   To the right of each value is a shortcut menu. These appear throughout STK. By clicking on them here, you can set units for Altitude, Speed, Acceleration, or Turn Radius. This comes in handy when you can't find or don't know the acronym for the unit you are looking for.
3. Extend the shortcut menu for Speed.
4. Select nm (nautical mile).
5. In the second shortcut menu, select hr (hour).
6. Set the value to 500. The aircraft flies from the first to the last waypoints at a speed of 500 nautical miles per hour.
7. Set the following for altitude and Turn Radius:

Option	Value
Altitude:	45000 ft
Turn Radius:	3 km

8. Click OK to close the Set All Grid Values dialog box.

9. Click Apply .

Set the animation time

You can jump to a waypoint in the 2D and 3D Graphics windows.

1. Select the second waypoint.

2. Click inside the Time cell.

3. Copy (Ctrl + C) the Time of the second waypoint.

4. Right-click in the Current Scenario Time field in the Animation Toolbar.

5. Select Paste.

SCENARIO TIME

6. Click the Enter key on your keyboard.

View in 3D

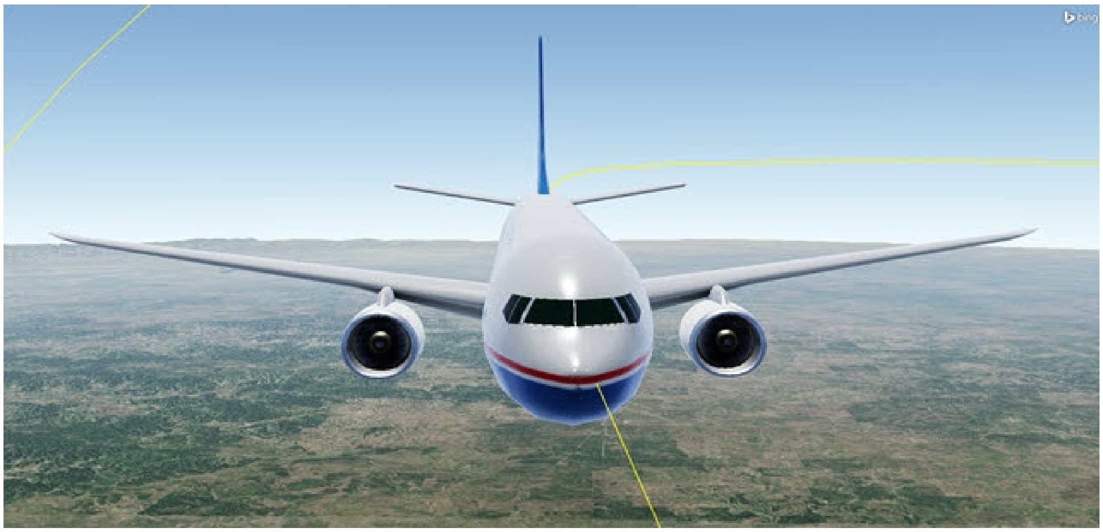
1. Bring the 3D Graphics window to the front.

2. Right-click on My_Plane () in the Object Browser.

3. Select Zoom To.

4. Using the left mouse button, create a head on view of My_Plane ( ).

All three waypoints are using the same values. The units converted back to the default units. The aircraft is flying the entire route at an altitude of 45000 feet MSL, at a speed of 500 nautical miles per hour and will require a turn radius of 3 kilometers at waypoint two. My_Plane ( ) is in the middle of the turn. Notice that there is no roll (banking) associated with the attitude.



NO ROLL IN TURN

2D GRAPHICS PROPERTIES

2D Graphics Attributes answer three basic questions about an STK object:

- What do you want to show?
- How do you want it to look?
- When do you want it to be seen?

1. Return to My_Plane's ( ) properties ( ).

2. Select the 2D Graphics - Attributes page.

Option	Description	Availability
Color	Select the standard or custom color in which to display the object's marker and, if applicable, its pattern or tracks.	All objects.
Line Style	Select the type of line to represent the object's pattern or tracks.	Objects that draw something on the Earth's surface, i.e. vehicles (tracks), sensors (patterns), and area targets (patterns or ellipses). Excluded are facilities, targets, planets, and stars.
Line Width	Select the width of the line to represent the object's pattern or tracks.	Same as Line Style.
Marker Style	Select the type of marker to represent the object's current position.	All objects except sensors.

3. Change Color, Line Style, and Line Width to whatever selections you want.

4. Click Apply .

View in the Graphics windows

1. Bring the 2D Graphics window to the front.

2. Zoom in or out in order to get a good view of MyPlane's ( ) flight route.

3. When finished, bring the 3D Graphics window to the front.

4. If needed, zoom to My_Plane ( ).

> **Note:** Changes made in the 2D Graphics Properties are applied to both the 2D Graphics and 3D Graphics windows.

3D GRAPHICS PROPERTIES

Unlike 2D Graphics properties which are seen in both the 2D and 3D Graphics windows, 3D Graphics properties can only be seen in the 3D Graphics window.

3D Graphics Properties - Vector is used to do the following:

- Control the display of vectors and other geometric elements, such as axes and angles, related to the Earth or other central body in the selected 3D Graphics window.
- Control the display of vectors and other geometric elements related to the selected object.

1. Return to My_Plane's ( ) properties ( ).

2. Select the 3D Graphics - Vector page.

3. Ensure the Vectors tab is selected.

4. Select the Show check box for Sun Vector.

5. Select the Axes tab.

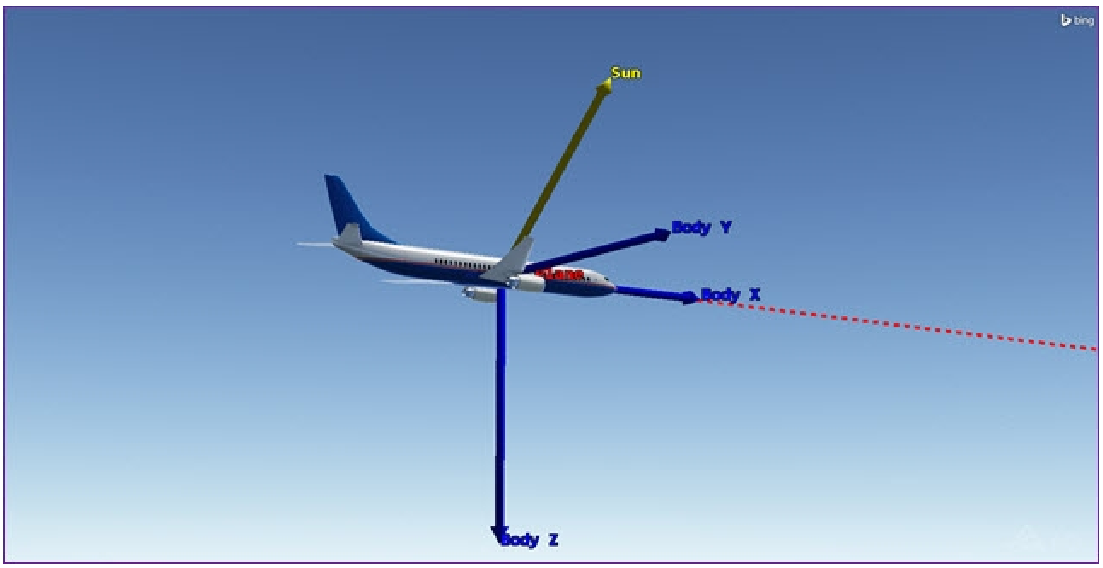
6. Select the Show check box for Body Axes.

7. Click Apply .

View in 3D

1. Bring the 3D Graphics window to the front.

2. If needed, Zoom To My_Plane ( ).



BODY AXES AND SUN VECTOR

Animate the scenario

The body axes remain fixed throughout the flight. Even when the Sun drops below the horizon, the sun vector continuously stays locked on the Sun.

1. Decrease Time Step ( ) to five (5.00) seconds in the Animation Toolbar.

2. Click Start ( ) to animate the scenario.

3. Click Reset ( ) when finished.

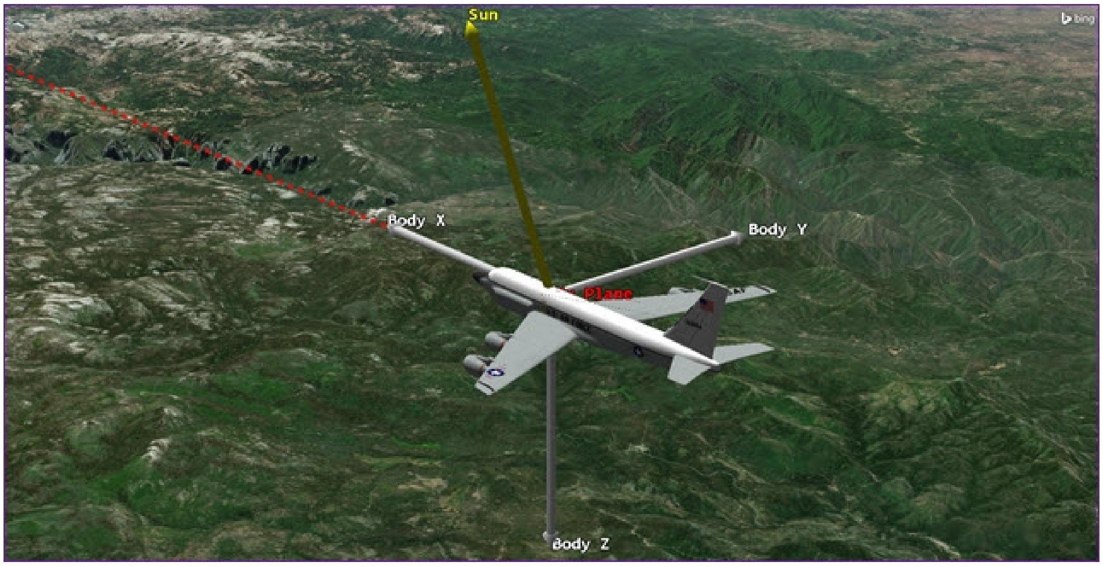
3D GRAPHICS MODEL

The 3D Graphics - Model page is used to specify a model to represent a given vehicle, facility, place, or target in the 3D Graphics window. You can scale the model and adjust the position of any model articulations. You can use models that install with STK, download models from the AGI Website (https://support.agi.com/3d-models/), or build your own models and use them in STK. The models are simply visual representations of your objects. Analysis is typically done from the center point of your object unless otherwise specified. You may want to change the model for a more realistic briefing or movie.

Supported model file types are:

- glTF models
- MDL models (.mdl)
- COLLADA models (.dae)

1. Return to My_Plane's ( ) properties ( ).
2. Select the 3D Graphics - Model page. The current model you see in the 3D Graphics window is the aircraft.glb.
3. Click the Model File: ellipses ( ) in the Model frame. All the models shown in the File dialog box come with the STK install.
4. Select any model (DAE File or Simulink Model) you'd like to use in the scenario.
5. Click **Open** .
6. Click **OK** .
7. Bring the 3D Graphics window to the front. You have a new model type representing the Aircraft ( ) object.



RC-135 RIVET JOINT MODEL

Place object

The Place ( ) object models a point of interest on the surface of the central body.

SEARCH BY ADDRESS METHOD (REQUIRES INTERNET)

1. Insert a Place ( ) object using the **Search by Address** ( ) method.
2. Type Pikes Peak in the Enter an address or other search criteria below: field when the STK: Insert by Address dialog box opens.
3. Select Pikes Peak, CO in the Results: list.
4. Click **Insert. Place(s)** .
5. Click **Close** to close the STK: Insert by Address dialog box.
6. Zoom To Pikes_Peak_CO( ).
7. Bring the 3D Graphics window to the front.

SEARCH BY ADDRESS / PIKES PEAK COLORADO

INSERT DEFAULT METHOD

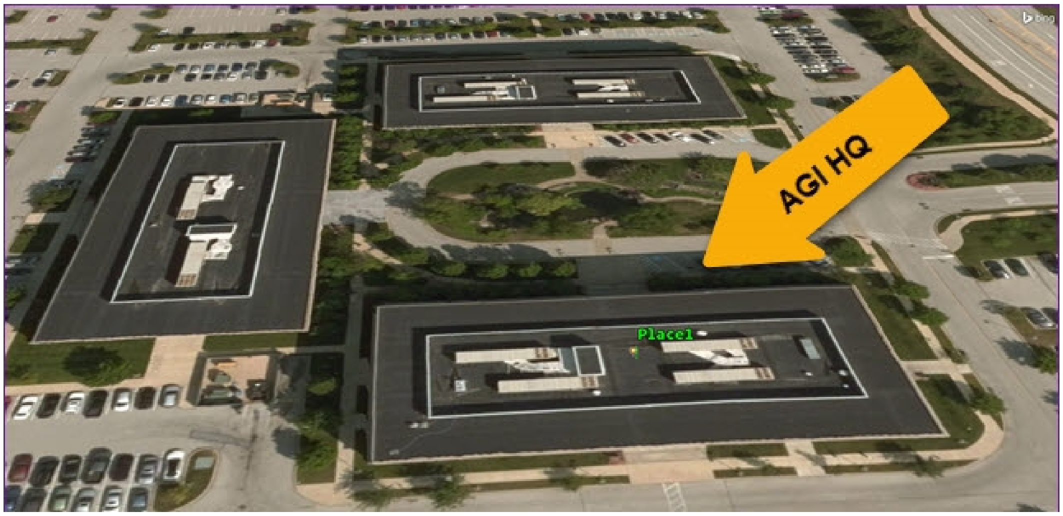
1. Insert a Place ( ) object using the Insert Default ( ) method.

2. Zoom To Place1 ( ).

   The Place ( ) object may have a different number than the one in this tutorial. If you have entered other Place ( ) objects prior to this, it may be something like Place2, Place3, etc.

3. Bring the 3D Graphics to the front.

   A Place ( ) object or a Facility ( ) object will default to AGI Headquarters.



PLACE OBJECT INSERT DEFAULT / AGI HEADQUARTERS

FROM CITY DATABASE METHOD

1. Insert a Place ( ) object using the **From City Database** ( ) method.
2. Type Exton in the Name: field when the Search Standard Object Data dialog box opens.
3. Click Search .
4. Right-click on Exton/Pennsylvania in the Results: list.
5. Select Insert Selected Item. This is another way to insert an item from the database.
6. Click Close to close the Search Standard Object Data dialog box.

VIEW IN 3D

1. Bring the 3D Graphics window to the front.
2. Using your right mouse button or the mouse scroll wheel, zoom out from Place1 ( ) until you see Place1 ( ) and Exton ( ).

EXTON AND PLACE1

The From City Database method inserts the city using a centroid for the city area. If you need an exact location, use the Search by Address method or the following procedure.

Set the height above ground of the facility

Set Place1 ( ) 30 feet above the ground to model the sensor on the roof of the building.

1. Return to Place1's ( ) properties ( ).
2. Enter 30 ft in the Height Above Ground: field.
3. Click OK .

All these steps were purposeful. You moved Place1 ( ) to the upper left corner of the building because there is a sensor located at that spot. Furthermore, the building's roof is 30 feet above the ground. These steps were used to put the Place1 ( ) in the correct location for future analysis in STK.

Summary

This tutorial began with understanding the purpose of the Insert STK Objects tool. Next, the Scenario ( ) object and its properties were discussed. This was followed by an in depth discussion of commonly used object in the Insert STK Objects tool, how to insert objects into the scenario, and which method to use during that insertion.

Part 3: Access Reports and Graphs

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro

Problem statement

Engineers and operators often need to determine the times one object can "access," or see, another object. In addition, they need to impose constraints on accesses between objects to define what constitutes a valid access. These constraints are numerous such as elevation angle, sun light or umbra restrictions, gimbal speed, range, etc. They also require the ability to create reports and graphs that summarize static data or show dynamic data during animation.

Solution

Building on your fundamental understanding of STK, use two important tools in STK to solve this problem:

- The Access Tool
- The Report & Graph Manager

What you will learn

Upon completion of this tutorial, you will learn:

- how the Access Tool functions by creating accesses between two or more objects
- how to find and use data providers with the Report & Graph Manager
- how to generate prebuilt reports using Quick Reports
- how to save data externally by Exporting Reports
- how to create Custom Reports for your scenario
- how to create 3D Graphics Dynamic Data Displays

Create a New Scenario

Create a new scenario.

1. Launch STK ( ).
2. Click Create a Scenario in the Welcome to STK dialog box.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	AccessReportsGraphs
Location:	Default
Start:	1 Jun 2020 18:00:00.000 UTCG
Stop:	2 Jun 2020 18:00:00.000 UTCG

4. Click OK when you are done.

5. Click Save () once the scenario loads. A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location and click **Save** .

> **Note:** Save () often during this lesson!

Inserting the satellite tracking station

A teleport is located in Castle Rock, Colorado. Enter the teleport into the scenario as a Facility () object.

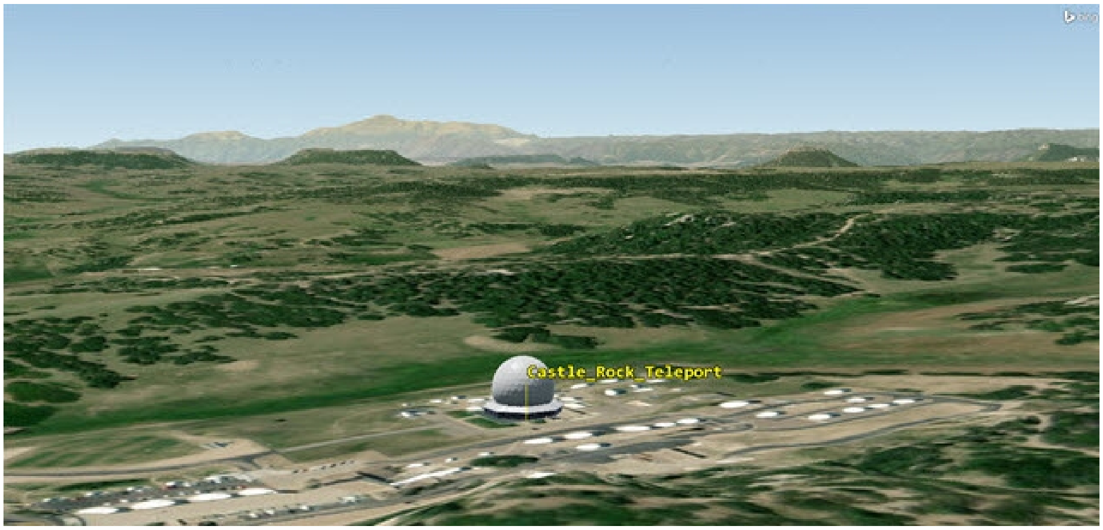
1. Select Facility () in the Insert STK Objects tool.
2. Select the From Standard Object Database () method.
3. Click **Insert...**
4. Type castle rock in the Name: field when the Search Standard Object Data dialog box opens.
5. Click **Search** .
6. Select Castle Rock Teleport using the INTELSAT Network selection.
7. Click **Insert** .
8. Click **Close** to close the Search Standard Object Data dialog box.

Viewing the tracking station in 3D

1. Bring the 3D Graphics window to the front.
2. Right-click on Castle_Rock_Teleport () in the Object Browser.

3. Select Zoom To.

4. Use your mouse to get a good view of Castle_Rock_Teleport ( ) and surrounding terrain.



CASTLE ROCK TELEPORT AND SURROUNDING TERRAIN

Streaming terrain from a Terrain Server

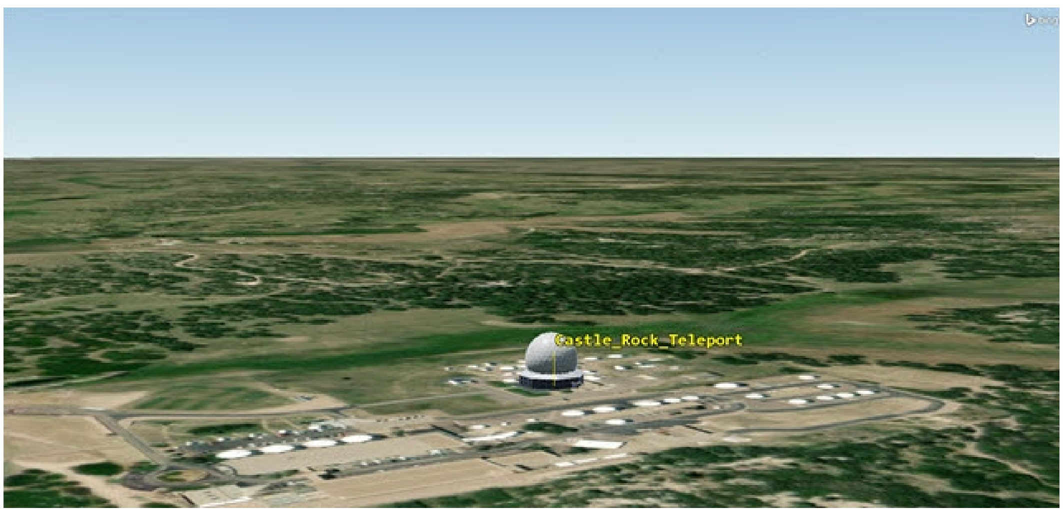
You can see that Castle_Rock_Teleport ( ) is located in mountainous terrain. Terrain Server distributes Earth terrain data for analysis and visualization. By default, STK connects to the AGI Terrain Server, which is available via an internet connection to all STK users. For the purposes of this scenario, disable Terrain Server.

1. Right-click on AccessReportsGraphs ( ) in the Object Browser.
2. Select Properties ( ).
3. Select the Basic - Terrain page when the Properties Browser opens.
4. Clear the Use terrain server for analysis check box in the Terrain Server frame.
5. Click OK to accept your changes and to close the Properties Browser.
6. Bring the 3D Graphics window to the front.

Editing Castle Rock Teleport's properties

Castle_Rock_Teleport () appears to be floating. STK is still referencing the altitude of Castle_Rock_Teleport () based on terrain data.

1. Open Castle_Rock_Teleport's () properties ().
2. Select the Basic - Position page when the Properties Browser opens.
3. Select the Use terrain data check box.
4. Click **Apply** to accept your changes and to keep the Properties Browser open.
5. Return to the 3D Graphics window.



CASTLE ROCK TELEPORT ON TOP OF THE WGS84

Castle_Rock_Teleport () is now referencing the surface of the WGS84.

Restricting the field-of-view of Castle Rock Teleport

You can restrict Castle_Rock_Teleport's () field-of-view by setting basic constraints, or you can restrict and visualize its field-of-view by using a Sensor () object.

1. Return to Castle_Rock_Teleport's () properties ().
2. Select the Constraints - Basic page.

   Note that Line of Sight is enabled. The Line of Sight constraint computes whether the line-of-sight between two objects is obstructed by the ground or in this case the WGS84 Ellipsoid.
3. Click OK to close the Properties Browser.

Inserting a Sensor object onto Castle Rock Teleport

Use a Sensor () object that mimics Castle_Rock_Teleport's () antenna field-of-view. For instance, if a combination of antennas provide a 360 degree field-of-view and a range of 1000 kilometers, you can use one Sensor () object to create that field-of-view.

1. Insert a Sensor () object using the Insert Default () method.
2. Select Castle_Rock_Teleport () in the Select Object dialog box.
3. Click OK .
4. Rename the Sensor1 () to CR_FOV. It's an acronym for Castle Rock field-of-view.

Setting the half angle of the sensor

A simple conic sensor pattern is defined by a simple cone angle.

1. Open CR_FOV's () properties ().
2. Select the Basic - Definition page.
3. Enter 90 deg in the Cone Half Angle: field.

Pay attention to half angles. In this instance you are setting a half angle of 90 degrees. Therefore, your field of view is actually 180 degrees.

4. Click **Apply** to accept your changes and to keep the Properties Browser open.

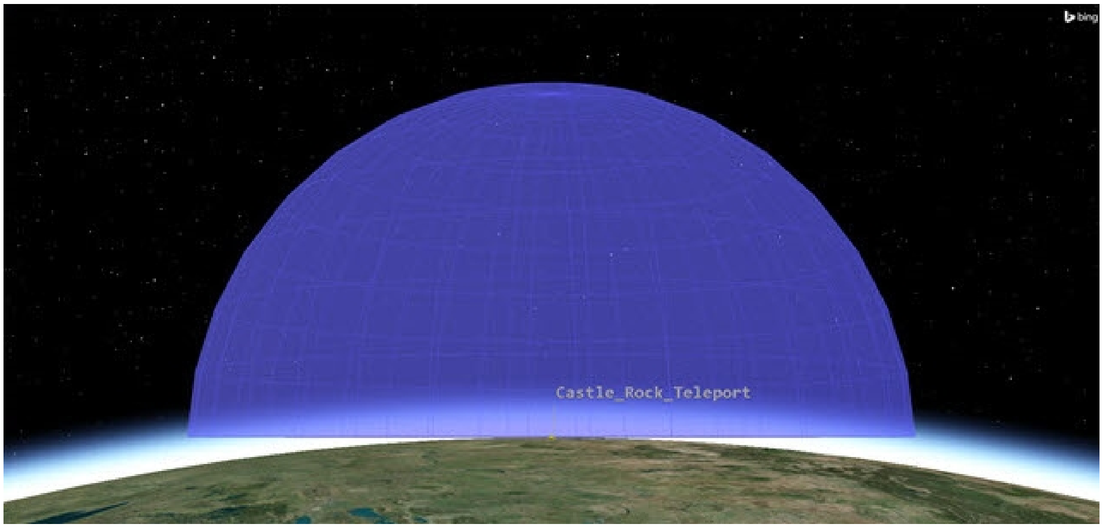
Setting constraints

Most of the Sensor ( ) object's basic constraints are identical to the Facility ( ) object's basic constraints. However, field-of-view is now available. Only Sensor ( ) objects have this constraint. If this check box is selected, access is denied if the associated object is not within the field-of-view as defined by the angle settings for the sensor type in question.

1. Select the Constraints - Basic page.
2. Select the Max: check box in the Range frame.
3. Enter 1000 km in the Max: field.
4. Click **OK** to accept your changes and to close the Properties Browser.

View the sensor in 3D

1. Bring the 3D Graphics window to the front.
2. Zoom To Castle_Rock_Teleport ( ).
3. Zoom back out far enough to see CR_FOV's ( ) field-of-view.

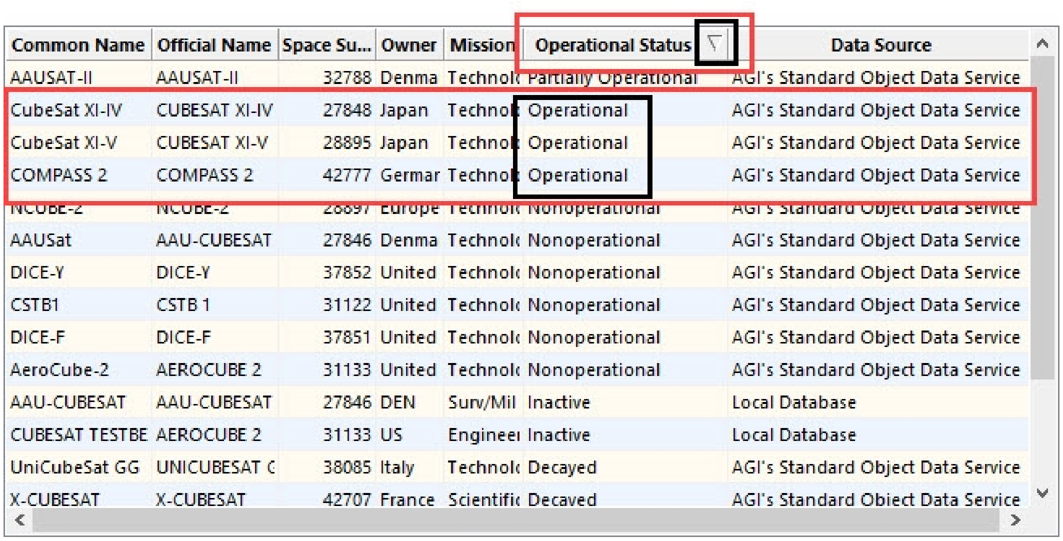


CR_FOV'S ( ) FIELD-OF-VIEW

Inserting three Satellites objects

Propagate three operational CUBESAT satellites using the Standard Object Database tool.

1. Insert a Satellite ( ) object using the From Standard Object Database ( ) method.
2. Type cubesat in the Name or ID: field when the Search Standard Object Data dialog box opens.
3. Click **Search** .



Common Name	Official Name	Space Su...	Owner	Mission	Operational Status	Data Source
AAUSAT-II	AAUSAT-II	32788	Denma	Technolc	Partially Operational	AGI's Standard Object Data Service
CubeSat XI-IV	CUBESAT XI-IV	27848	Japan	Technol	Operational	AGI's Standard Object Data Service
CubeSat XI-V	CUBESAT XI-V	28895	Japan	Technol	Operational	AGI's Standard Object Data Service
COMPASS 2	COMPASS 2	42777	Germar	Technol	Operational	AGI's Standard Object Data Service
NCUBE-2	NCUBE-2	28897	Europe	Technolc	Nonoperational	AGI's Standard Object Data Service
AAUSat	AAU-CUBESAT	27846	Denma	Technolc	Nonoperational	AGI's Standard Object Data Service
DICE-Y	DICE-Y	37852	United	Technolc	Nonoperational	AGI's Standard Object Data Service
CSTB1	CSTB 1	31122	United	Technolc	Nonoperational	AGI's Standard Object Data Service
DICE-F	DICE-F	37851	United	Technolc	Nonoperational	AGI's Standard Object Data Service
AeroCube-2	AEROCUBE 2	31133	United	Technolc	Nonoperational	AGI's Standard Object Data Service
AAU-CUBESAT	AAU-CUBESAT	27846	DEN	Surv/Mil	Inactive	Local Database
CUBESAT TESTBE	AEROCUBE 2	31133	US	Engineer	Inactive	Local Database
UniCubeSat GG	UNICUBESAT (	38085	Italy	Technolc	Decayed	AGI's Standard Object Data Service
X-CUBESAT	X-CUBESAT	42707	France	Scientific	Decayed	AGI's Standard Object Data Service

4. In the Results: field, click Operational Status until the arrow points down.

5. Select the following operational satellites:

   - CUBESAT XI-IV
   - CUBESAT XI-V
   - COMPASS 2

   > **Note:** If you are offline or searching the local databases, the Common Name of the Cubesats might be different. You can find the correct satellites to insert by searching for each satellite listed above individually and looking at the Official Name column.

6. Click Insert .

7. Ensure all three satellites inserted into the scenario.

8. Click Close to close the Search Standard Object Data dialog box

---

Using the Access Tool

An access is defined by two or more objects - a primary object and an associated object or objects- for which the access is computed. Once an access is created, it maintains a close relationship with the defining objects. If either of the defining objects is changed in such a way that the access times may be altered, the access is automatically recomputed. Also, if either of the defining objects is removed from the scenario, the access is automatically removed. You want to analyze when the CUBESAT satellites pass through CR_FOV's ( ) field-of-view.

1. Click Access ( ) in the STK Tools toolbar.

2. Within the Access Tool, click Select Object... to the right of Access for: field.

3. Select CR_FOV ( ) in the Select Object dialog box.

4. Click OK .

"Access for:" now shows Castle_Rock_Teleport-CR_FOV. This is the object you're looking from.

5. Select all three Satellite ( ) objects in the Associated Objects list.

6. Click Compute

You are computing accesses from CR_FOV ( ) to all three Satellite ( ) objects. You can see that once you compute the access, the three Satellite ( ) objects' graphics have changed in the list. The names of the Satellite ( ) objects are now in bold with an asterisk. There is also a key ( ) icon with a green ( ) check mark, which represents access. In the 2D graphics window, there is a static highlight between the two objects. In the 3D graphics window, a line connects the two objects when you animate the scenario and the objects have access each other.

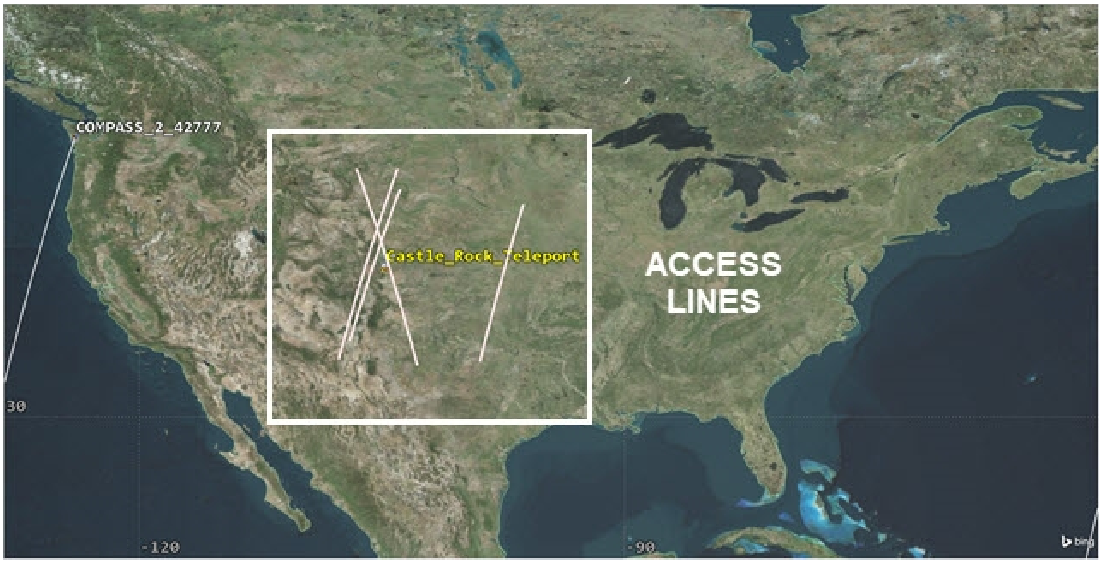
Viewing accesses in the 2D Graphics window

Prior to generating any reports or graphs, you can quickly view any accesses you might have be looking at the 2D Graphics window. The Graphics options available via the Access tool allow you to define the display of accesses in the 2D Graphics window using the options available in the Graphics field of the Access window.

1. Bring the 2D Graphics window to the front.

2. Center your view on Castle_Rock_Teleport ( ).

3. Zoom out until you see the Continental United States.



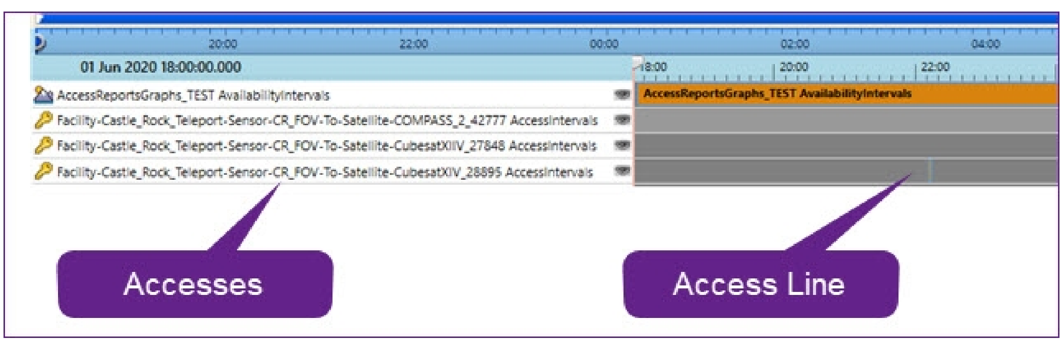
2D GRAPHICS ACCESS LINES

The access lines don't tell you which satellite was seen, but shows you when satellites passed through the sensor's field-of-view and the sensor accessed them.

Viewing accesses in the Timeline View

The Timeline View can be used to visualize a variety of time intervals within your scenario.

1. Look at the Timeline View.



TIMELINE VIEW WITH ACCESSES

You can see the three accesses and the times that actual accesses occur. It's possible, depending on your analysis period, that some or all of your satellites do not have an access.

2. Return to the Access Tool.

Generating an Access Report

In the Reports frame, clicking Access... generates a report that provides access times between one object and one or more selected objects. Global statistics are provided if more than one object is selected.

1. Ensure all the satellites are selected in the Associated Objects list.
2. Click Access... in the Reports frame.

   If there is an access between the Sensor ( ) object and a Satellite ( ) object, the report tells you when and for how long the access takes place. If an access doesn't exist, the report will say No Access Found.
3. Scroll through the report to become familiar with the layout.
4. Close the access report once you are done.

Generating an Access Graph

In the Graphs frame, clicking Access... generates a graph that provides access times between one object and one or more selected objects.

1. Return to the Access Tool.
2. Click Access... in the Graphs frame.

   When you generate a graph, the zoom in function is automatically on.
3. Locate the first access in the graph and using your mouse, hold down the left mouse button, draw a box around the access. This can be done multiple times until the graph is filled with the one access.
4. Place the cursor at the beginning of the access. A text box will appear with information about the access start time.

GRAPH WITH ACCESS START TIME

5. Click Zoom Out ( ) until you see the whole graph.

6. Close the access graph when finished.

Generating an Azimuth Elevation Range Report (AER)

In the Reports and Graphs frames, clicking AER... generates an access report or graph with azimuth, elevation, and range data. In order to interpret the data correctly, you should understand the following:

1. Return to the Access Tool.

2. Ensure all the satellites are selected in the Associated Objects list.

3. Click AER... in the Reports frame.

   Since the access is taking place from an object on the ground, an azimuth of zero (0) degrees is True North. The elevation is based on the central body (WGS84). The range is calculated from the center point of the FROM object to the center point of the TO object. Remember, the Satellite ( ) objects must enter the Sensor ( ) object's field-of-view in order to be accessed.

4. Scroll through the report to become familiar with the layout.

5. Close the AER report once you are done.

Extending CR_FOV's ( ) range

Extend CR_FOV's ( ) range to see how it affects your data.

1. Open CR_FOV's ( ) properties ( ).
2. Select the Constraints - Basic page when the Properties Browser opens.
3. Enter 1500 km in the Range frame's Max: field.
4. Click **OK** to accept your change and to close the Properties Browser.

Refresh the access report

The access report is showing the old data. Apply the new range constraint to the report.

1. Click Refresh (F5) ( ) in the access report toolbar. You also have the option of clicking F5 on your keyboard to refresh a report.
2. Compare your new data to your old data. You have the same number of accesses but your durations are longer.

Changing the reports units

In the access report toolbar, clicking Report Units ( ) opens the Units dialog box that allows you to change the units of measure for the report. The Units dialog box will display all dimensions relevant to the report.

1. Click Report Units ( ) in the report toolbar.
2. Select the Time Dimension in the Units: Access dialog box.

3. Select Minutes (min) in the New Unit Value list.

4. Click OK .

5. Duration is now reported in minutes instead of seconds.

Quick Reports

Unlike .txt and .csv files, a Quick Report is saved inside of STK. Also, if you save a report or graph as a Quick Report and make property changes that affect the data, the next time you open the Quick Report, the changes will be reflected. If you don't want to lose old data, save it outside of STK.

1. Click Save as quick report () in the access report toolbar.

2. Click Quick Report Manager... () at the top of STK in the Data Providers Toolbar.

3. Change the quick report's name to Sensor to CUBESAT.

4. Click the Enter key on your keyboard.

   Without having the Access Tool open, you can generate the report from the Quick Report Manager by clicking Create . Show on Load will automatically open the report whenever you open the scenario.

5. Disable the Show on Load option.

   You can add any text to the Description field.

6. Click OK .

7. Close the access report.

8. Close the Access Tool.

Viewing the quick report

1. Return to the Quick Report Manager... ( ).
2. Extend the shortcut menu.
3. Select Sensor to CUBESAT.

Setting the Scenario Time from a Report

Using the quick report (access report) there are a couple of simple ways to set your animation time from the report. You will focus on the first access start time.

1. Right-click on the first access start time.
2. Select Start Time in the shortcut menu.
3. Click Set Animation Time in the second shortcut menu.
4. Look in the Animation Toolbar's Current Scenario Time field. It matches the start time of the first access.
5. Click Reset ( ) in the Animation Toolbar.
6. Return to the access report.
7. Highlight the first access start time.
8. Right-click and select Copy. (Ctrl+C) will also work.
9. Click inside Current Scenario Time field.
10. Right-click and select Paste. (Ctrl+V) will also work.
11. Press Enter on your keyboard.

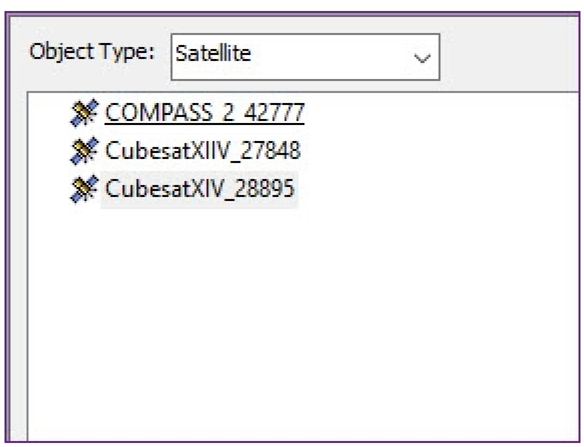
Your scenario's animation has jumped to the first instance that CR_FOV ( ) accesses CubesatXIV_28895 ( ).

Using the Report & Graph Manager

You can generate the following types of output for most STK objects using the Report & Graph Manager which is available from the Analysis menu or the Data Providers toolbar:

- Reports that summarize static data.
- Reports that update during animation. These reports, called dynamic displays, enable you to view changes to selected elements over a period of time.
- Graphs that summarize static data.
- Graphs that update during animation. These graphs, called strip charts, enable you to view changes to selected elements over a period of time.

1. Click Report & Graph Manager ( ) in the Data Providers toolbar.
2. Change the Object Type: to Satellite in the upper left corner of the Report & Graph Manager.
3. Select CubesatXIV_28895 ( ) in the Object List.



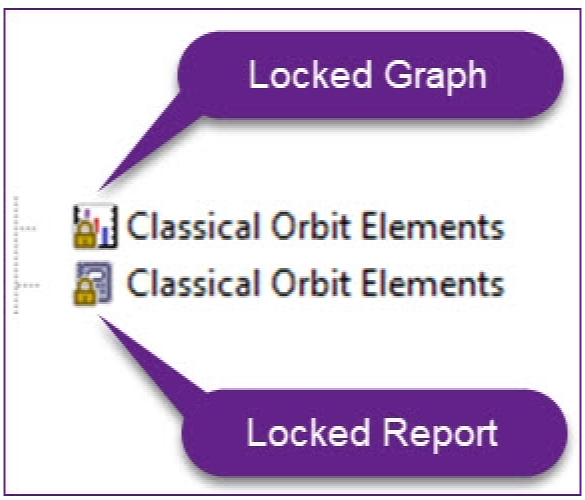
OBJECT TYPE FOR A REPORT OR GRAPH

Multiple objects can be selected, but for this scenario, focus on CubesatXIV_28895 ( ).

Using Data Providers, Groups and Elements

Data Providers, Groups and Elements are the organizing principles of the Data Provider Functionality. STK provides hundreds of prebuilt reports and graphs. You have the option of using prebuilt reports and graphs or you can customize the properties of a static or dynamic report or graph. You can also create your own reports and graphs. It's a good idea to understand the hierarchy of Data Providers, Groups and Elements.

1. Close the report.
2. Return to the Report & Graph Manager.
3. Look at the very top of the styles field. The Classical Orbit Elements () report is now available in the My Favorites () folder.
4. Take a close look at Classical Orbit Elements located in the Installed Styles list. One is a graph style and one a report style. Notice the locks.



REPORTS AND GRAPHS

The reports and graphs located in the Installed Styles list cannot be customized. However, they can be duplicated and the duplicate can be customized. In this scenario, you're focusing on CubesatXIV_28895 (). Maybe you're preparing for a briefing. Instead of using the argument of perigee, true anomaly and mean anomaly data provider elements, you require J2000 X Y Z Cartesian Position elements. You can duplicate and customize the Classical Orbit Elements report by removing the elements you don't need and adding the required elements.

Data Providers by Object

The content of a report or graph is generated from the selected data providers for the report or graph style. To select data providers for a report or graph, right-click the style in the Report & Graph Manager and select Properties.

1. Right-click on the Classical Orbit Elements ( ) report in the Installed Styles list.
2. Select Properties ( ).
3. Select the Content page when the Properties Browser opens.

   The left side shows all the data providers for the object type (in this case a Satellite ( ) object) and on the right side are the Report Contents.
4. In the Report Contents list, select Classical Elements-J2000-Semi-major Axis.
5. Return to the Data Providers list. You can see the hierarchy of Classical Elements (Data Provider)- J2000 (Group)- Semi-major Axis (Element).

Changing the units of measure

You can change units of measure for a report style or a displayed report.

1. Return to the Report Contents list and select Classical Elements-J2000-Semi-major Axis.
2. Below Report Contents, click **Units...**

   The current distance unit is being reported in kilometers (km).
3. Clear the Use Defaults check box in the Units: dialog box.

4. Select Meters (m) in the New Unit Value list. Your custom report will use meters instead of kilometers for the semi-major axis.

5. Click **OK** to close the Units: dialog box.

Report Contents

As previously stated, you will replace argument of perigee, true anomaly and mean anomaly data provider elements with J2000 X Y Z Cartesian Position elements.

1. In the Report Contents list, select the following:
   - Classical Elements-J2000-Arg of Perigee
   - Classical Elements-J2000-True Anomaly
   - Classical Elements-J2000-Mean Anomaly
2. Click **Remove** .
3. Remove the asterisk (*) at the top of the Data Providers list, in the Filter field.
4. Type Cartesian.
5. Click **Filter** . This narrows down your choices to only those data providers containing Cartesian elements.
6. Expand (⊞) Cartesian Position.
7. Expand (⊞) J2000.
8. Move (→) X, Y, and Z to the Report Contents list.
9. If desired, use the up (↑) and down (↓) arrows to place elements where desired.
10. Click **OK** to accept your changes and to close the Properties Browser.
11. Click **OK** after reading the warning.

Recall that earlier it was mentioned that you can't customize a locked report unless it is duplicated first. Since you went straight to the properties of the locked report and did not duplicate, the warning tells you where to find your new report.

Generate the report

1. Expand (⊞) My Styles ( ) in the Styles list.
2. Right-click on Classical Orbit Elements ( ).
3. Select Rename.
4. Rename Classical Orbit Elements ( ) to My Classical Orbit Elements.
5. Click **Generate...**

   The custom report is showing the semi-major axis in meters and the J2000 X Y Z Cartesian Position elements. The report is in 60 second increments which can be changed in the Time Properties field if desired or selecting **Show Step** .
6. Close the report when you are finished.

Using Dynamic Display

Using Generate As: Report/Graph, static data was generated for the report. To generate animated data, select Generate As: Dynamic Display/Strip Chart and click **Generate...** . Data will update during animation of the scenario for the report.

1. Select the Dynamic Display/Strip Chart option in the Generate As: field.
2. Click **Generate** .
3. Click Reset ( ) in the Animation toolbar.
4. Click X Real-time Animation Mode ( ).

5. Click Start ( ) to animate the report. The dynamic display updates as the scenario animates.
6. Click Reset ( ) when finished.
7. Close all open reports and the Report & Graph Manager.

Using 3D Graphics Data Display

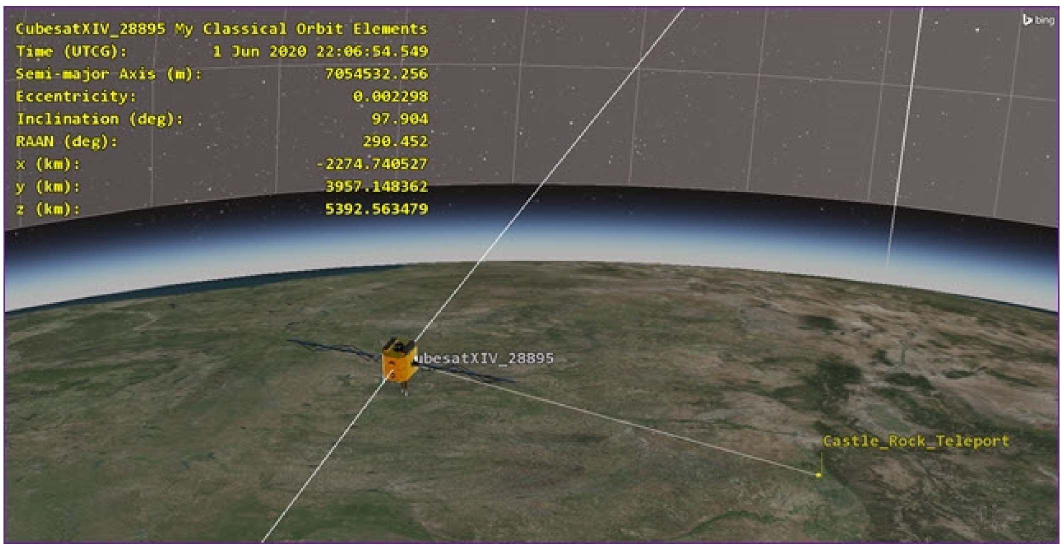
3D Graphics Data Display will display dynamic data for the specified object in the 3D Graphics window. This feature is useful when presenting information that requires both visual and textual data. If you record a movie of your scenario, the data will appear in the movie.

1. Open CubesatXIV_28895's ( ) properties ( ).
2. Select the 3D Graphics - Data Display page.
3. Click **Add...**
4. Select My Classical Orbit Elements in the Add a Data Display dialog box.
5. Click **OK** to close the Add a Data Display dialog box.

   Settings in the Position frame automatically places the data in the top left portion of the 3D Graphics window. You can add more data to the window and then change the position. Note other selections for appearance and background.
6. Open the Font Size: shortcut menu in the Appearance frame.
7. Select Medium.
8. Click **OK** to accept your changes and to close the Properties Browser.

Viewing the data

1. Bring the 3D Graphics window to the front.
2. Extend the Stored Views ( ) shortcut menu.
3. Select Sat First Access.



3D GRAPHICS WINDOW DYNAMIC DATA

The stored view now shows the moment CubesatXIV_28895 ( ) enters CR_FOV's ( ) field-of-view and important data pertaining to CubesatXIV_28895 ( ) is displayed in the 3D Graphics window.

4. Click Start ( ) in the Animation toolbar to animate the scenario. Data updates dynamically in the 3D Graphics window.
5. Click Reset ( ) when finished.

Summary

You began by inserting Castle Rock Teleport and creating an antenna field-of-view by using a Sensor ( ) object. Next, you propagated three operational CUBESAT satellites. Using the Access Tool, you computed an access report, an access graph and then an azimuth elevation range report between the Sensor ( ) object and the three CUBESAT satellites. Next, you focused on and created an access to CubesatXIV_28895 ( ). Using the access report, you learned how to create external .txt and .csv files from the report and how to export data from STK. Using the access report you learned how to set animation time and how to create a quick report and a stored view. The Report & Graph Manager came next where you learned what data providers, groups and elements are and how to create a custom report. You ended by placing dynamic data from the custom report onto the 3D Graphics window.

Movies and Visual Data Files

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro

Problem Statement

Engineers and operators often need resources to prepare visual presentations for briefings, talks, speeches and demonstrations. In this scenario, an aircraft is flying an important mission that you wish to simulate using a video and an STK Visual Data File.

Solution

Upon completion of this tutorial, you will learn how to:

- Create a simple movie that can be embedded in a PowerPoint presentation or played for an audience
- Convert an STK scenario into a visual data file (VDF)
- Display the VDF in STK Viewer, which does not require an STK license
- Create a first rate briefing experience to both the presenter and the audience

What you will learn

Upon completion of this tutorial, you will be able to:

- Make Movies with STK
- Create Visual Data Files
- Use STK Viewer

Creating a New Scenario

Create a new scenario.

1. Launch STK ( ).
2. Click Create a Scenario in the Welcome to STK dialog box.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	STK_Movies_VDFs
Location:	Default
Start:	1 Mar 2023 23:00:00.000
Stop:	+ 4 hrs

4. When you finish, click OK .
5. Click Save ( ) once the scenario loads. A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location and click Save .

Note: Save ( ) often during this lesson!

Post-typhoon aerial photography flight route

You will simulate an aircraft's flight route across Japanese airspace. Your aircraft will fly over the following islands and cities in the order shown:

- Naha, Okinawa
- Amami Oshima, Kagoshima
- Minamidaito, Okinawa
- Back to Naha, Okinawa

Inserting Naha Airport as a Place object

1. Select Place ( ) in the Insert STK Objects Tool.
2. Select the Search by Address ( ) method.
3. Click Insert...
4. Type Naha Airport in the Enter an address or other search criteria below: field in the STK: Insert by Address dialog box.
5. Select Naha Airport, Japan (latitude 26.19583, longitude 127.64583).
6. Click Insert Place(s) .

Note: The Insert by Address option requires an internet connection. If you do not have an internet connection you can select the Define Properties option and set the lat/lon manually.

Inserting Amami Oshima as a Place object

1. Type Amami in the Enter an address or other search criteria below: field.
2. Select Amami, Japan (latitude 28.37724 longitude 129.49374).
3. Click **Insert Place(s)** .

Inserting Minamidaito as a Place object

1. Type Minamidaito in the Enter an address or other search criteria below: field.
2. Select Minamidaito, Japan (latitude 25.82889 longitude 131.23187).
3. Click **Insert Place(s)** .
4. Click **Close** to close the STK: Insert by Address dialog box.

Using the Label Declutter option

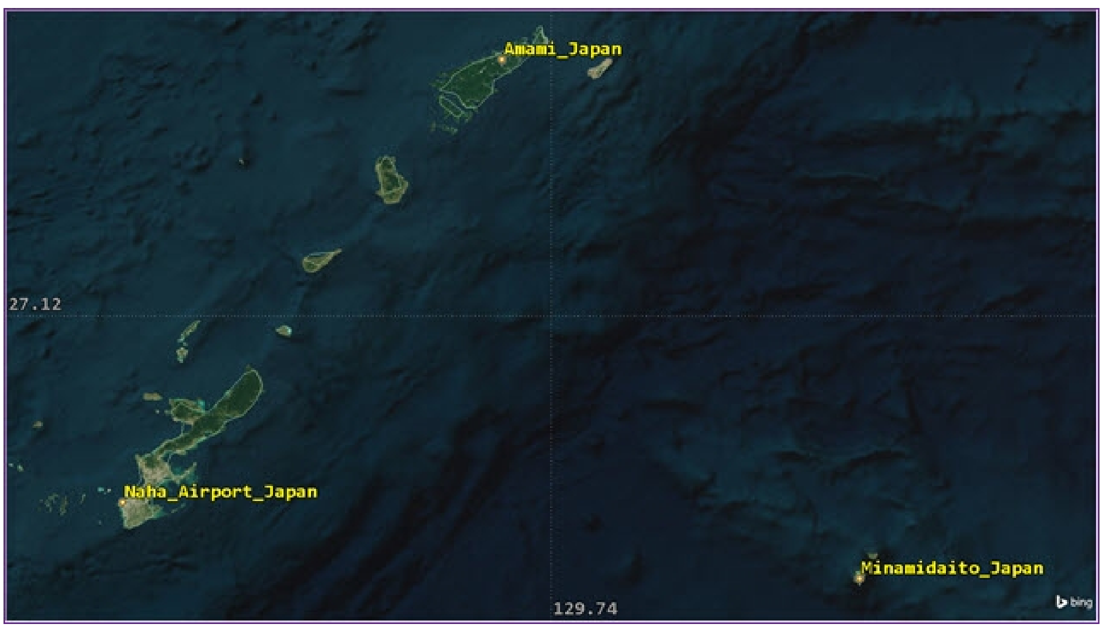
Label Declutter moves labels away from the central body and towards the viewer, keeping the labels from being obscured by the terrain.

1. Click Properties () in the 3D Window Defaults tool bar.
2. Select the Details page when the Properties Browser opens.
3. Select the Enable check box in the Label Declutter frame.
4. Click **OK** to accept your change and to close the Properties Browser.

Inserting an Aircraft object

You will insert an Aircraft ( ) object. Adjust the altitude, speed, turn radius and attitude.

1. Insert an Aircraft ( ) object using the Insert Default ( ) method.
2. Right-click on Aircraft1 ( ) in the Object Browser.
3. Select Rename.
4. Rename Aircraft1 ( ) to PhotoMission.
5. Bring the 2D Graphics window to the front.
6. Maximize the 2D Graphics window.
7. Zoom in to the 2D Graphics window so that all three Place ( ) objects are visible and centered.



Modifying the Aircraft object's properties

1. Right-click on PhotoMission ( ) in the Object Browser.
2. Select Properties ( ).
3. Select the Basic - Route page when the Properties Browser opens.
4. Open the Reference: shortcut menu in the Altitude Reference frame.
5. Select MSL (Mean Sea Level).
6. Bring the 2D Graphics window to the front by clicking the 2D Graphic... tab near the bottom of STK.

> **Note:** Clicking the tab is a safe way to bring the 2D Graphics window to the front when you have an Aircraft ( ) object's properties open and you are on the Basic - Route page. If you inadvertently click on the map, you will create a waypoint.

Creating waypoints for the Aircraft object

To keep things simple and focus on movie making and creating VDFs, you'll use the clicking on the 2D Graphics window method to create waypoints for PhotoMission ( ). By clicking on the 2D Graphics window, you won't fly to precise locations. You'll fly to the point you clicked. Start at Naha.

1. Click as close as you can to the Naha Place ( ) object symbol's point in the 2D Graphics window.

CLICK THE PLACE OBJECT SYMBOL'S SHARP POINT

2. Click as close as you can to the Amami Place ( ) object symbol's point.

3. Click as close as you can to the Minamidaito Place ( ) object symbol's point.

4. Click as close as you can to the Naha Place ( ) object symbol's point.

   Due to the default turn radius, your waypoints won't be overhead of Amami or Minamidaito. We'll fix that shortly.

5. Return to PhotoMission's ( ) properties by clicking on the PhotoMission... tab ( ) below the 2D Graphics window.

Adjusting the aircraft's altitude, speed, and turn radius

Adjust the altitude, speed, and turn radius using Set All... .

1. Click Set All... .
2. Select the Altitude, Speed and Turn Radius check boxes in the Set All Grid Values dialog box.
3. Set the following:

Option	Value
Altitude:	10000 ft
Speed:	200 mi/hr
Turn Radius:	1 km

4. Click OK to close the Set All Grid Values dialog box.
5. Click Apply to save your changes and to keep the Properties Browser open.
6. Return to the 2D Graphics window.

Notice that by creating a smaller turn radius, PhotoMission is much closer to the waypoints. You could further adjust them in the 3D Graphics window using the 3D Object Editing tool if desired.

Adjusting the attitude

Define the attitude profile for PhotoMission ( ) by using a coordinated turn. This profile computes the roll (banking) of an aircraft based on a balancing of the forces acting on the aircraft, assuming a zero angle of attack and no slip condition.

1. Return to PhotoMission's ( ) properties ( ).
2. Select the Basic - Attitude page.
3. Open the Type: shortcut menu in the Basic frame.
4. Select Coordinated Turn.
5. Click Apply to save your changes and to keep the Properties Browser open.

Changing the Aircraft object's model

PhotoMission's ( ) model is a glTF (GL Transmission Format) Model which looks similar to a Boeing 737. Here, you will learn to change it to a smaller model that resembles a two-engined turbo prop aircraft. The model type is an MDL Model (.mdl).

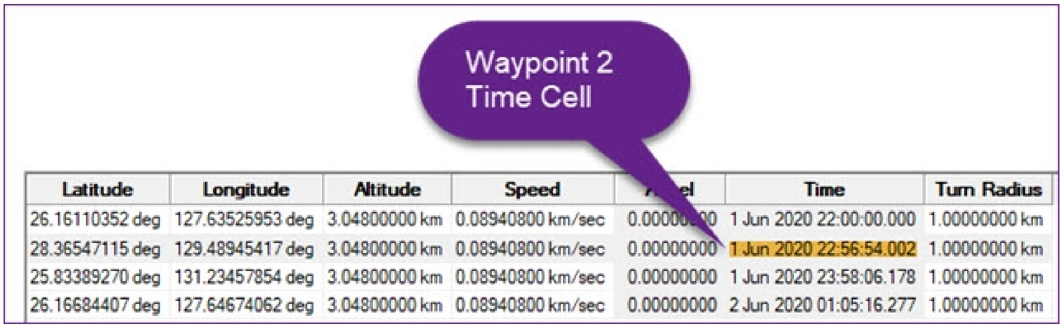
1. Select the 3D Graphics - Model page.
2. Click the Model File: ellipsis ( ) in the Model frame.
3. Select the commuter.mdl file in the File dialog box.
4. Click **Open** .
5. Click **Apply** to save your changes and to keep the Properties Browser open.
6. Select the Basic - Route page.

Preparing the Scene

There are many **ways to create a movie** inside of STK. For the purposes of this movie, you'll use one of many.

The second point (waypoint) is when PhotoMission ( ) is overhead Amami_Japan ( ). You will make a movie that begins ten (10) seconds prior to and ends ten (10) seconds after the waypoint's time. Jump to the waypoint's time. Your time will be different than the time showed in the example.

1. Go to the Time cell of point two.
2. Click in the cell to select the time.



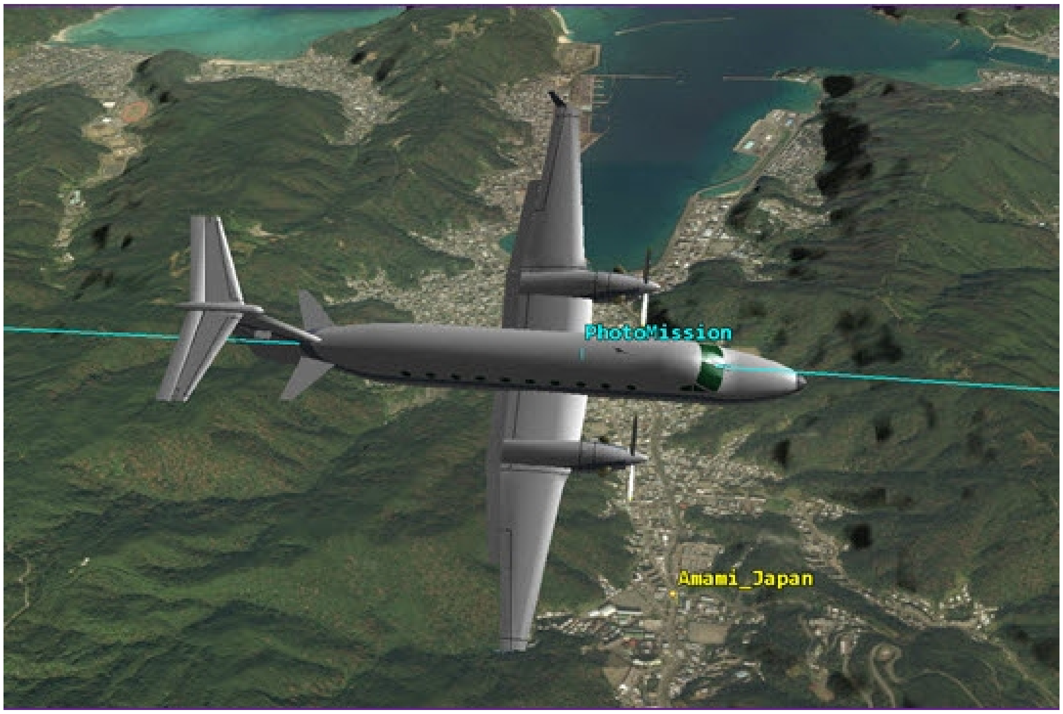
Latitude	Longitude	Altitude	Speed	[illegible]	Time	Turn Radius
26.16110352 deg	127.63525953 deg	3.04800000 km	0.08940800 km/sec	[illegible]	1 Jun 2020 22:00:00.000	1.00000000 km
28.36547115 deg	129.48945417 deg	3.04800000 km	0.08940800 km/sec	0.00000000	1 Jun 2020 22:56:54.002	1.00000000 km
25.83389270 deg	131.23457854 deg	3.04800000 km	0.08940800 km/sec	0.00000000	1 Jun 2020 23:58:06.178	1.00000000 km
26.16684407 deg	127.64674062 deg	3.04800000 km	0.08940800 km/sec	0.00000000	2 Jun 2020 01:05:16.277	1.00000000 km

WAYPOINT 2 TIME CELL

3. Press Ctrl + C (copy) on your keyboard.
4. Highlight the time in the Current Scenario Time field in the Animation Toolbar.
5. Press Ctrl + V (paste) on your keyboard.
6. Press the Enter key on your keyboard.

Viewing in 3D

1. Bring the 3D Graphics window to the front
2. Right-click on PhotoMission ( ) in the Object Browser.
3. Select Zoom To.
4. Using your mouse, set up the view so that you can see both PhotoMission ( ) and Amami_Japan ( ).



PHOTOMISSION AND AMAMI_JAPAN EXAMPLE

Editing PhotoMission's properties

1. Return to PhotoMission's () properties ().
2. Select the 2D Graphics - Attributes page.
3. Clear the following check boxes in the Inheritable Settings frame:
    - Inherit from Scenario
    - Show Route
    - Show Route Marker
4. Click Apply to save your changes and to keep the Properties Browser open.
5. Bring the 3D Graphics window to the front.

PHOTOMISSION WITHOUT FLIGHT ROUTE LINE

3D Graphics Data Display

Placing important dynamic data which is displayed on the 3D Graphics window enhances both the movie and the presentation.

1. Return to PhotoMission's ( ) properties ( ).
2. Select the 3D Graphics - Data Display page.
3. Select the Show LLA Position (Latitude, Longitude, Altitude) Show check box. You can make changes to its Position and Appearance if desired.
4. Click **OK** to accept your changes and to close the Properties Browser.

3D Graphics window size

The 3D Graphic window has to be set at certain sizes when you make a movie. For instance, a good size to set the window for a movie you'll place on a PowerPoint slide is 640 x 480. This isn't the only size you can use, but for this scenario, stick with this. If your 3D Graphics window is maximized, you need to restore the window to normal size.

1. Return to the 3D Graphics window.
2. Ensure the window returns to its normal size by clicking Restore.

Setting Animation Time

Earlier, you set your animation time to the second waypoint which is in the Current Scenario Time field. You will start the movie 10 (ten) seconds prior to that time. The following is an example of what to do:

- Let's say the time in the Current Scenario Time field is: **1 Mar 2023 23:56:20.123**
- Round down ten seconds earlier to the nearest integer: **1 Mar 2023 23:56:10.000**

1. Round down the time by ten seconds in the Animation Toolbar Current Scenario Time field.
2. Press Enter on your keyboard.
3. Make sure you're satisfied with your view. Once you start recording the movie, do not touch the 3D Graphics window.

Creating a Stored View

1. Click Stored Views ( ) in the 3D Graphics window toolbar.
2. Click **New** in the Stored View: 3D Graphics 1 - Earth dialog box.
3. Set the View Name to Movie Time.
4. Click **OK** to close the the Stored View: 3D Graphics 1 - Earth dialog box.

   By creating this view, if you were to Reset ( ) your scenario, you can quickly jump back to this time and view in the 3D Graphics window.

5. Click X Real-time Animation Mode ( ) in the Animation toolbar.

Movie Timeline Plugin

The **Movie Timeline Plugin** helps you record animations from STK. You can also record a movie using 3D Graphics window properties where It is found on the **Record Movie** page. In this scenario, use the Movie Timeline Plugin. There are a lot of features in the Movie Timeline Plugin, but to keep things simple, you'll use the Record from the Movie Timeline button.

1. Open the View menu at the top of STK.
2. Select Toolbars in the shortcut menu.
3. Select Movie Timeline in the second shortcut menu.
4. Click Record ( ) in the Movie Timeline tool bar.

Movie Wizard

The Movie Wizard will help you walk through important steps in creating your movie.

On the left side are pages starting with Filename & Format. If you follow the sequence from top to bottom, you will make a fairly effortless movie.

Filename and format

Save your movie in your scenario directory using H.264 format.

1. Select the Filename & Format page.
2. Click **Save as...** in the Choose the filename to use during movie recording: frame.
3. Browse to your scenario folder (e.g. C:\Users\username\Documents\STK 12\STK_Movies_VDFs).
4. Change the File name: to any name you desire (e.g. First Movie.h264).
5. Click **Save** .
6. Leave the format as a H.264 (.mp4).
7. Click **Next** .

Selecting a graphics window to record

You can select which window you are recording. You're recording the 3D Graphics window.

1. Ensure 1 - 3D Graphics 1 - Earth option is selected.
2. Click **Next** .

Changing the resolution

Here, you resize the 3D Graphics window using preset sizes.

1. Open the Preset: shortcut menu in the Choose the resolution of the recorded movie: frame.
2. Select Large.

   In order for this to work, the 3D Graphics window needs to be restored to normal size (which you accomplished previously). If your 3D Graphics window is maximized you will receive a "WINDOW SIZE MISMATCH" error.

   This is a very common mistake that people make. If you receive this error, you will need to restore the 3D Graphics window to normal size.
3. Click **Next** .

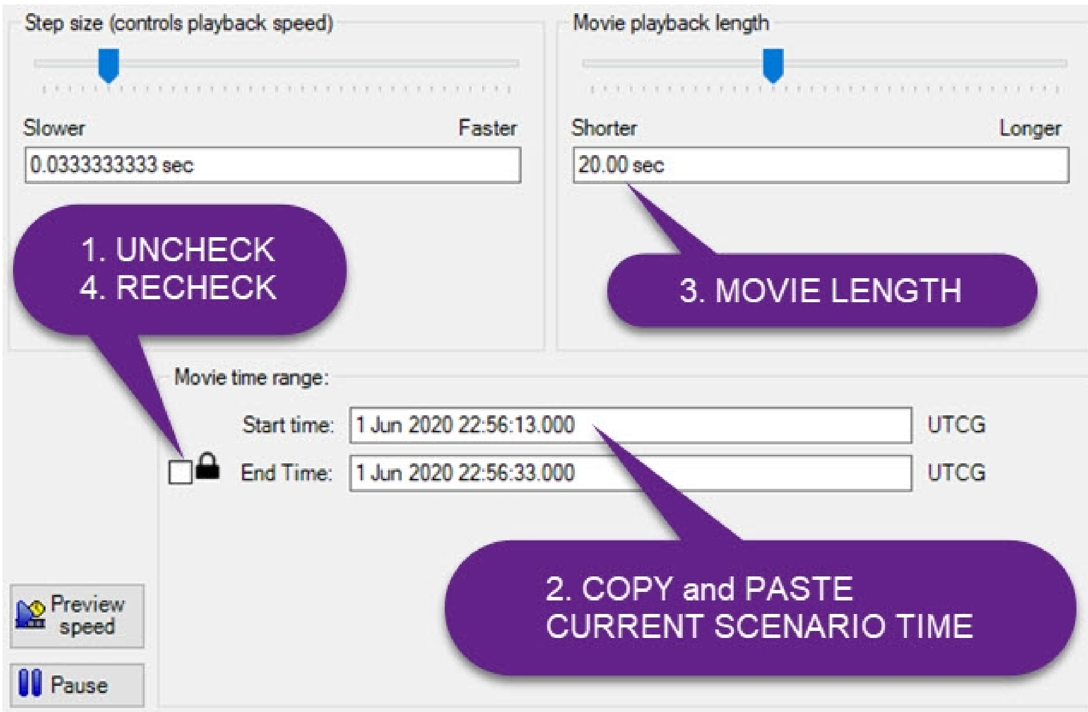
Advanced camera controls

If you're making a more advanced movie using paths created with the **3D Camera Control Toolbar**, you would select the path you want to record.

1. Ensure your 3D Graphics window is using your stored view. If required, return to the 3D Graphics window toolbar, extend the Stored Views pull-down menu to select Movie Time.
2. Return to the Movie Wizard.
3. Select None (use current view).
4. Click **Next** .

Video time and length

Take your time on this page. It's important to follow the following steps:



TIME & LENGTH STEPS

1. Clear the black lock ( ) check box.
2. Copy (Ctrl + C) the time in the Current Scenario Time field.
3. Paste (Ctrl + V) it in the Movie time range: Start time: field.
4. Highlight the time and units in the Movie playback length Shorter / Longer field.
5. Enter the value 20 into the Shorter / Longer field.
6. Press the Tab key on your keyboard. This will automatically enter sec (seconds) and change the Movie time range: End Time: to twenty (20) seconds past the Start time.

7. Select the black lock ( ) check box.

8. Click **Next** .

Video size and quality

In the 3D Graphics window, aliasing is the process by which smooth curves and other lines become jagged because the resolution of the graphics device or file is not high enough to represent a smooth curve. Anti-aliasing is a technique for diminishing jagged - stair step-like lines that you want to be smooth.

1. Extend the Anti-aliasing: pull-down menu to view the settings.
2. Leave the default setting of 3x3 - Good Quality.
3. In the Recorded image quality, and estimated file size: field, change Quality to High Quality @ 1080 if required. This adjusts the bitrate and changes the estimated maximum size of the recorded movie.
4. Click **Next** .

Beginning your recording

Here you can view the summary and go back to make any changes you feel are necessary. Remember, it's a good idea not to manipulate the 3D Graphics window once the recording begins.

> **Note:** You can enable the Record in parallel option to use STK's Parallel Computing ability.

1. Click **Begin Record** ( ) once you are prepared to record. Sit back and wait until the recording is complete.
2. Click **Yes** when you are prompted to view the recording.
3. When you are finished admiring your Oscar winning creation, close the media player and return to STK.
4. Click **Finish** in the Movie Wizard.

Resetting the Scenario Animation Time

Using the Movie Wizard, when you create the start and stop time of your movie, it sets those times in the Scenario ( ) objects Basic - Time Animation field. It's a good idea to reset these time so that you can animate your complete analysis time (in this case four hours).

1. Open STK_Movies_VDFs ( ) properties ( ).
2. Select the Basic - Time page.
3. Select the following check boxes in the Animation frame:
    - Use Analysis Start Time
    - Use Analysis Stop Time
4. Click **OK** to select your changes and to close the Properties Browser.

Summary

You created a scenario that was used to record a movie and save a visual data file. You began by entering ground locations, inserting an Aircraft ( ) object, building it's flight route and changing the model to match the actual mission aircraft. Preparing the movie scene, you removed lines and points, kept labels and created a 3D Graphics data display to enhance situational awareness showing important latitude, longitude and altitude data dynamically. Setting the 3D Graphics window to normal size, you created a stored view of the time and view of when the movie would start and what you wanted to see in the movie. You learned how to enable the Movie Timeline Plugin and use all of its functionality by recording a movie. You created important data reports that you needed for a briefing and packaged up the scenario as a visual data file. Finally, you were introduced to the functionality of STK Viewer and its power in delivering a top notch briefing to your audience.

Part 5: Introduction to Connect

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro

Problem statement

Programmers, engineers, and operators often need resources to easily build applications that communicate with STK. Having a spreadsheet containing data, they need to transfer the data into and out of STK quickly and easily. Many of the engineers and operators are not programmers. They need a simple to understand language and syntax with which to create ways to efficiently populate objects into STK and extract data from STK or create automation.

Solution

You will learn what an STK Connect command is and how to find and use the Connect Command Library. Using the STK Integration capability and the API Demo Utility, explore the Connect Command Library and become familiar with some simple connect commands used to quickly and easily populate objects into and obtain analytical data from an STK scenario.

What you will learn

Upon completion of this tutorial, you will understand the following:

- The Connect Command Library
- Simple Connect Commands
- The API Demo Utility

Create a new scenario

Create a new scenario.

1. Launch STK ( ).
2. Click Create a Scenario in the Welcome to STK dialog box.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	STK_Connect
Location:	Default
Start:	Default
Stop:	Default

4. Click OK once you are done.
5. Click Save ( ) once the scenario loads. A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location and click Save .

Note: Save ( ) often during this lesson!

Preparing STK

For this scenario, the Timeline View and the Insert STK Objects tool won't be used. You can close them.

1. Close the Timeline View.
2. Close the Insert STK Objects tool.

The Web Browser

In STK, the Web Browser is a web browser that is an integrated part of the workspace.

1. Click New Integrated Web Browser ( ) on the Default toolbar.
2. Click Browse ( ) in the Web Browser - AGI - Resources web browser toolbar.
3. Click **Example HTML Utilities** in the Open dialog box.
4. Select STK Automation.
5. Click **Open** .
6. Select API Demo.
7. Click **Open** .
8. Select API Demo Utility.
9. Click **Open** .

Customizing your workspace

You can dock the API Demo Utility to the bottom of the STK workspace.

1. Right-click on the Web Browser - API Demo Utility title.
2. Select Dockable.
3. Place your cursor on the Web Browser - API Demo Utility title (usually docks below the Object Browser).
4. Hold down your left mouse button.
5. Move the web browser to dock it at the bottom of STK.
6. Open the Window menu at the top of STK.
7. Select Tile Vertically.

API Demo Utility

Connect commands are normally sent to STK from outside of STK using a TCP/IP connection or a COM interface. In this scenario, you'll use the API Demo Utility to practice and understand Connect commands. The API Demo Utility functions inside of STK, therefore no outside connections are required (e.g. TCP/IP). The API Demo Utility is a great tool with which to practice Connect commands prior to using them in an actual script.

1. Look at the API Demo Utility.
    - Examples: On the left side of the API Demo Utility are examples. When you click an example, the associated Connect command appears in the Code Sandbox. Connect isn't compiled code. Connect is simply a string of text written in a way that STK understands. Connect is sometimes referred to as "The Language of STK".
    - Code Sandbox: The Code Sandbox is where you enter your Connect commands or load the prebuilt example Connect commands.

- Connect and Object Model radio buttons: When you load an example Connect command, you can view it as a Connect command or select Object Model to see examples of how a line of code might look inside an application like MATLAB.
- Run Code: Clicking Run Code will send your Connect command to your scenario.

- Output: The Output window is used if you send a Connect command which returns data such as the data inside an access report.

Using the New command

The New command allows you to create a new scenario or add a new object to the current scenario.

```
Syntax: New <ApplicationPath> <ClassPath> <NewObjectName> {NewOptions}
```

1. Select Add facility in the In the API Demo Utility's Examples list.
2. Break down the string of text located in the Code Sandbox:

String of Text in Add Facility	Meaning
`New`	Connect Command
`/`	ApplicationPath
`*/Facility`	ClassPath
`MyFacility_Con`	NewObjectName

- Wildcards can be used in Connect commands. To understand wildcards, view the Help page WILDCARDS IN OBJECT PATHS.
- The `<ApplicationPath>` is the path to the instance of the current Application (e.g. STK).
- The `<ClassPath>` specifies the full class path of the object to be created. In this case, it's the new Facility ( ) object you're entering into the scenario.

- The `<NewObjectName>` is the name of the Facility ( ) object.
    - Object Names can not be more the 64 characters in length.
    - Object Names can contain only alphanumerics, underscores and hyphens.
    - Object names, in Connect, are not case-sensitive, however Class names are case-sensitive.
    - An object name cannot be "_Default" or "end" (regardless of case), as these are reserved words in STK.

3. Click **Run Code** .

A Facility ( ) object has been entered into the scenario using its default properties.

Understanding the Connect Command Library

There is a whole section in STK Help devoted to Connect. You can use the commands in the Connect library to easily build applications that communicate with STK.

1. Extend the Help menu.
2. Select STK Help.
3. Select Integrating with STK on the left.
4. Select Connect Command Library.

> **Note:** There's a lot of information in the Connect Command Library to include breaking down Connect commands by object, 2D and 3D Graphics windows, by capability, etc. To keep things simple, we'll focus on the API Demo Utility Examples. You can find much more in depth training in the Optional Third-Party Programs (Level 2 - Advanced Training), specifically **Integrating STK with MATLAB**, **Integrating STK with Python** and **Integrating STK with Excel**. A Level 3 - Focused / Problem Specific lesson that uses Connect is **Using STK Connect to Plan a Predator Mission**.

Alphabetical listing

The Alphabetical listing includes all Connect commands, regardless of their groupings.

1. Select Alphabetical Listing of Connect Commands.
2. Select N at the top of the page.
3. Select the New command.

   The page describes the command, syntax, related commands, options, and examples. Whenever you're starting to write Connect commands, look at the examples. You'll have to change them to work with your object types and such, but it's a great place to start.

SetPosition command

Use the SetPosition command to set the position of a facility, place, target or area target.

1. Return to the alphabetical listing.
2. Select S at the top of the page.
3. Select SetPosition (Facility, Place, Target & Area Target).
4. Ensure you have the correct syntax: SetPosition <ObjectPath> [{Type}] {CoordType} <Parameters>
5. Scroll down the page until you find the {CoordType} <Parameters> chart.
6. Note the Geodetic <Parameters> <Lat> <Lon> {<Altitude> | Terrain} [MSL].
7. Return to STK.

Understanding the Connect command

Before you run the code, look at the SetPosition command.

1. Select Modify facility in the In the API Demo Utility's Examples list.
2. Right-click on MyFacility_Con ( ) in the Object Browser.
3. Select Properties ( ).
4. Select the Basic - Position page.
5. Notice the SetPosition code in the Code Sandbox matches the Connect command syntax (e.g. Type, Latitude, Longitude, Altitude).
6. Click **Cancel** to close the Properties Browser.
7. Return to the API Demo Utility.

Modifying the SetPosition code

1. Remove 0.0 (altitude) at the end of the SetPosition Connect command.
2. Type Terrain at the end of the Connect command.

   Since you have streaming terrain from Terrain Server, by removing the altitude and inserting Terrain, the Facility object will be placed on top of the terrain at the coordinates in the command.

   The second command is another New command. Note the path. It follows the object type to object name like you see it in the Object Browser. The New command inserts a Sensor ( ) object and attaches it to the MyFacility_Con ( ).

3. Click Run Code .

   MyFacility_Con ( ) has new coordinates and an attached Sensor ( ) object named MyFacSensor_Con.

Inserting a Satellite ( ) object

We won't keep jumping back and forth between STK and the Connect Command Library. However, feel free to go there on your own as we proceed through the training. Add a Satellite ( ) object to the scenario and name it MySat.

1. Select Add satellite In the API Demo Utility's Example list.
2. Change the Satellite ( ) object's name from MySatellite_Con to MySat.
3. Click Run Code .

   MySat ( ) has been added to the scenario but it needs to be propagated.

Propagating MySat ( )

1. Select Modify satellite in the API Demo Utility's Examples list.

   The SetState Classical command sets the orbit state of the satellite using classical coordinates.

```
Syntax: SetState <VehObjectPath> Classical {Propagator} {NoProp |
{TimeInterval}} <StepSize> {CoordSystem} "<OrbitEpoch>" <SemiMajorAxis>
<Eccentricity> <Inclination> <ArgOfPerigee> <RAAN> <MeanAnom>
```

2. Compare the text in the Code Sandbox to the syntax and change the following:

Option	Value

Object name	MySat
Inclination	45 (deg)
RAAN	180 (deg)

Note: The value for the SemiMajorAxis is in meters which is the default distance unit when using Connect. Default distances in STK are in kilometers.

3. Click Run Code .

Inserting an Aircraft ( ) object

1. Select Add aircraft in the API Demo Utility's Examples list.
2. Look at the code in the Code Sandbox.

The New command inserts the Aircraft ( ) object. Then you set the propagator to Great Arc, reference mean sea level (MSL) and create waypoints.

Command	Description
SetPropagator	Set the propagator of a great arc vehicle.
AltitudeRef	Set the altitude reference for a Great Arc vehicle.
AddWaypoint	Add waypoints to a great arc vehicle.

3. Click Run Code .

Modifying MyAircraft_Con ()

1. Select Modify aircraft in the API Demo Utility's Examples list.
2. Look at the code in the Code Sandbox.

   The Waypoints command and the Clear WaypointOption clears the original waypoints and AddWaypoint inserts new waypoints.

Command	Description
Waypoints	Clear all waypoints from a great arc vehicle.

3. Click **Run Code** .

Computing an access

Compute an access from MySat () to MyFacility_Con ().

1. Select Compute access in the API Demo Utility's Examples list.
2. Look at the code in the Code Sandbox.

Command	Description
Access	Calculate access intervals between two objects.

3. Change the Satellite name from MySatellite_Con to MySat.
4. Click **Run Code** .
5. Bring the 2D Graphics window to the front. You will see access lines above MyFacility_Con ().
6. Look at the API Demo Utility - Output.

You can see the full path to each object followed by individual accesses.

Adding vectors

Add a vector which points from the Facility () object to the Satellite object.

1. Select Add vectors in the API Demo Utility's Examples list.
2. Look at the code in the Code Sandbox.

Command	Description
VO SetVectorGeometry	Define the display of geometric components in the 3D Graphics window.
VO View	Set parameters for the view in a 3D window.

3. Change the Satellite name from MySatellite to MySat in the VO SetVectorGeometry code line.
4. View both lines of code.
5. Click **Run Code** .
6. Bring the 3D Graphics window to the front.
7. Right-click on MyFacility_Con () in the Object Browser.
8. Select Zoom To.

To view the vector pointing from MyFacility_Con ( ) to MySat ( ), you might have to set your view in the 3D Graphics window so that you're under the terrain. The vector is only visible above the terrain when MyFacility_Con ( ) has an access to MySat ( ).

9. Click Start ( ) to animate the scenario.

10. Click Reset ( ) when finished.

11. Save ( ) your work.

Summary

This was an introduction to the STK Connect module and the Connect Command Library. You were introduced to the API Demo Utility which is just one of a few tools that come with STK that you can use to send Connect commands.

- STK Button Tool: The Button Tool is a Perl script with a graphical user interface (GUI) that you can use to associate STK Connect commands with buttons.

- Send_A_Connect_Command.htm: Located in Example HTML Utilities. This is a utility that allows you to send a Connect command to STK by typing it into a text field and submitting it. The alphabetical listing of Connect commands can be displayed to help look up different commands.

Connect is an easy way to automate functions and quickly populate scenarios (e.g. Using STK Connect to Plan a Predator Mission).

Become Level 1: STK Certified

Now that you have completed Fundamentals training, you are well-prepared to complete the STK Level 1: STK Certification test. The STK Certification is the first level of certification and validates your ability to perform fundamental skills needed to be productive with STK.

What's in the Test?

The STK Certification test consists of one exercise scenario and you have 14 days from registration date to complete Certification. The following objectives are tested:

- Model Your Systems - KML, Aircraft, Satellite, Sensor, Constraints
- Analyze Your Systems - Access Tool, Report & Graph Manager, Quick Reports
- Visualize Your Data - 3D Models, Stored Views, Timeline View
- Extend STK - Connect and Object Model
- Share Your Work - VDF, STK Data Federate, Movies, Snapshots

Once you earn your STK Certification, you will receive a Level 1: STK Certified gift. Register now to take the Level 1: STK certification test (http://www.agi.com/training/#cert).

STK Level 2 - Advanced

STK Level 2 - Advanced training builds off of STK Level 1 - Beginner. You will take simulations from STK Fundamentals a step further with advanced analysis capabilities and tools to quantify and measure mission effectiveness.

Evaluation License

You can obtain the necessary license for the training by visiting **http://licensing.agi.com/stk/evaluation** or contacting AGI Support at **support@agi.com** or 1-800-924-7244.

The Level 2 - Advanced Training is a series of tutorials designed to take a user through STK's advanced capabilities.

Once you have completed these tutorials, you will be ready to take the level 2 STK Master Certification test! Visit www.agi.com/training-and-certification#cert/ (free for U.S. and Canada). Upon registration for the level 2 Master Certification, you will receive an email confirmation with an attachment for a 14 day demo license. This license provides you access to all the capabilities needed to complete the certification. This license is for use with STK 12.2 or older. If you are using STK 12.3 to complete the STK Certification test, please contact AGI Support at **support@agi.com** or 1-800-924-7244 for an updated license file.

Optional Third-Party Programs

Several of the tutorials use MATLAB, Python, and/or Excel. While not required to complete the tutorials, these programs are very useful to have when using STK. If you do not have these programs, you can open example files in a text editor to view the syntax.

Tutorial	Capabilities
Introduction to the Pro Capabilities Learn how to add terrain and imagery to the scenario.	STK Pro

Customize Analysis with Analysis Workbench Learn how to use STK's Analysis Workbench capability to build custom geometric, temporal, and logical operations through STK.	STK Pro, *Analysis Workbench*
Compute Coverage Over Regions Learn how to analyze global and regional coverage provided by various assets.	STK Pro, *Coverage*
Introduction to AzEl Mask Tool and Volumetrics Learn how to use the AzEl Mask Tool and build a volumetric object.	STK Pro, *Analysis Workbench*, *Coverage*
Perform Trade Studies with Analyzer Learn how to use STK's Analyzer capability to automate STK trade studies and parametric analyses.	STK Pro, *Analyzer*
Introduction to Communications Learn how to define and analyze detailed communication systems.	STK Pro, *Communications*
Introduction to Radar Learn how to build radar system models to simulate and analyze system performance.	STK Pro, *Radar*, *Coverage*
Integrating STK with MATLAB Learn how to control STK through an external application like MATLAB.	STK Pro, Integration
Integrating STK with Python Learn how to control STK through an external application like Python.	STK Pro, Integration
Integrating STK with Excel Learn how to control STK through an external application like Excel.	STK Pro, Integration
Model Aircraft Missions with Aviator Learn how to model a sequence of curves parameterized by well known performance characteristics of aircraft.	STK Pro, *Aviator*
Introduction to Advanced CAT Tool Learn how to use STK's Conjunction Analysis capability to avoid a satellite collision.	STK Pro, *CAT*
Design Trajectories with Astrogator Learn how to use STK's Astrogator capability to place a satellite in orbit.	STK Pro, *Astrogator*
Air to Missile Observations with EOIR Learn how to use STK's EOIR capability by modeling an air-to-air observation mission.	STK Pro, *EOIR*

Note: For the STK 10 version of this training, visit

http://help.agi.com/StartTraining/StartTraining1013.htm

Part 6: Introduction to the Pro Capabilities

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: This lesson is an introduction to STK's *Pro* capability. Pictures, graphs, and data snippets are used as examples only. The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results. Throughout the tutorial, there are hyperlinks that take you to the appropriate STK Help area which further expand your knowledge on the subject.

Credits: ISERV, NASA

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro

Problem Statement

Engineers and operators require a quick way to determine if local terrain is affecting visibility between ground sites and satellites for a variety of purposes such as communications, imaging, and general situational awareness. In this tutorial, there is a GPS monitoring station in the vicinity of Mount St. Helens. A **USGS Digital Elevation Model (DEM)** file contains terrain data for the area requiring analysis. Raw satellite imagery is available of Mount St. Helens which will provide situational awareness of the analytical area when converted as an inlay. A further need exists to create color elevation imagery of the area to be used in a briefing and in documentation.

Solution

Using STK, load a DEM file to analyze the impact of local terrain on accesses between a ground station and GPS satellites. Create a color elevation image, and convert a raw satellite image that can be used as an inlay for visualization and situational awareness. Change the DEM file into a STK Terrain File (pdtt) which can be used to visualize terrain in the 3D Graphics window.

Upon completion of this tutorial, you will be able to:

- Use terrain data for analysis and visualization
- Build a Constellation object
- Build a Chain object

Create a New Scenario

Create a new scenario with a run time of twenty four (24) hours.

1. Launch STK ( ).
2. Click the Create a Scenario ( ) button.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	STK_Pro
Start:	Default
Stop:	Default

4. When you finish, click OK.

5. When the scenario loads, click Save (). A folder with the same name as your scenario is created for you.

6. In the Save As window, verify the scenario name and location and click Save.

> **Note:** Save Often!

U.S. Geological Survey Data

> **Note:** The DEM file used in this tutorial is located in the install directory. Take a moment to download the file. DO NOT unzip the folder. Follow the instructions in the tutorial to use the file.

1. Create a folder on your Desktop called Terrain.

2. Browse to the location of the DEM file using the following:

   - STK 11: C:\Program Files\AGI\STK 11\CodeSamples\CodeSamples.zip\SharedResources\Scenarios\Events

   - STK 12: C:\Program Files\AGI\STK 12\CodeSamples\CodeSamples.zip\SharedResources\Scenarios\Events

3. Locate and copy the file named hoquiam-e.dem.

4. Paste the hoquiam-e.dem file into the Terrain folder you created on your desktop.

Analytical Terrain

The *Pro* capability adds realism to system models. Building on the fundamental capabilities of STK, *Pro* introduces more sophisticated modeling through advanced access constraints, flexible sensor shapes, complex visibility links, more object tracks and digital terrain data.

Load the locally available DEM terrain data file to be used for analysis and visualization into the scenario.

1. Open STK_Pro's ( ) properties.
2. Select the Basic - Terrain page.
3. Disable Use terrain server for analysis.

   You're using a local terrain file for both analysis and visualization. By turning off streaming terrain, you are simulating what you'd see in a setting that doesn't have an Internet connection.

4. In the Custom Analysis Terrain Sources field, on the right, click Add.
5. When the Open window appears, change Files of type: to USGS DEM (DEM).
6. Browse to the Terrain folder containing the hoquiam-e.dem file.
7. Select hoquiam-e.dem and click Open.
8. Click OK in the properties window to load the hoquiam-e.dem file as analytical terrain.

Terrain Regions Display

Display an outline around the imported terrain region on the 2D Graphics window. The following turns off Bing maps and switches to the default Basic.bmp. If you don't have an Internet connection, this is the default map.

1. Bring the 2D Graphics window to the front.
2. Open the 2D Graphics window's properties ( ).
3. On the Imagery page, enable Image File: and ensure Basic.bmp is selected (default).

   The following will outline international borders and all the states of the United States and provinces of Canada.

4. Select the Details page.
5. In the Map Details field, click on and highlight the following (leave RWDB2_Coastlines highlighted):

- RWDB2_International_Borders
- RWDB2_Provincial_Borders

Finally, create a yellow outline of the hoquiam-e.dem file's location.

6. In the Terrain Regions Display field, enable Show Extents.
7. Click OK.
8. Bring the 2D Graphics window to the front and zoom in to the state of Washington.

   The yellow box in the southwest corner of the state is the location of the hoquiam-e.dem file. Analysis inside the box can be done using local terrain. Analysis outside the box will take place on the WGS84.

SHOW EXTENTS

9. Zoom in to the terrain extents.

Color Elevation Imagery

The **Create Color Elevation Imagery utility** allows you to create images from terrain data that show elevation data colored by height (for example, blue for sea level, green for land, and white for mountain tops). This is useful if you need to visualize terrain but lack imagery or if you want to put the emphasis on height rather than the content of the image.

1. On the 2D Graphics window, zoom in to the terrain region display and move it to the right of your map.

2. Open the Utilities menu and select Create Color Elevation Imagery.

3. When the Create Color Elevation Imagery utility opens, move it next to the terrain region display.

4. Enter the following extents which match the hoquiam-e.dem extents:

Option	Value
North Lat	47 deg
West Lon	-123 deg
East Lon	-122 deg
South Lat	46 deg

5. Click the Get Min/Max Altitude button.

   Displays the minimum and maximum altitude values of the region selected in the 2D Graphics window. This range can help if you use explicit colors. Set HSV for the rendering of elevation data during the conversion process. The resulting image is colored so that elevations are drawn with a linearly interpolated color between the minimum altitude and the maximum altitude, depending on the elevation. Change the minimum altitude values. The default values create a dark blue color. You are landlocked so use a corresponding HSV code that removes the blue.

6. Set the following Min Altitude: values:

Option	Value
Hue	0.25
Saturation	0.75
Value	0.20

7. Change Output File / Format to JPEG 2000 Image (jp2).

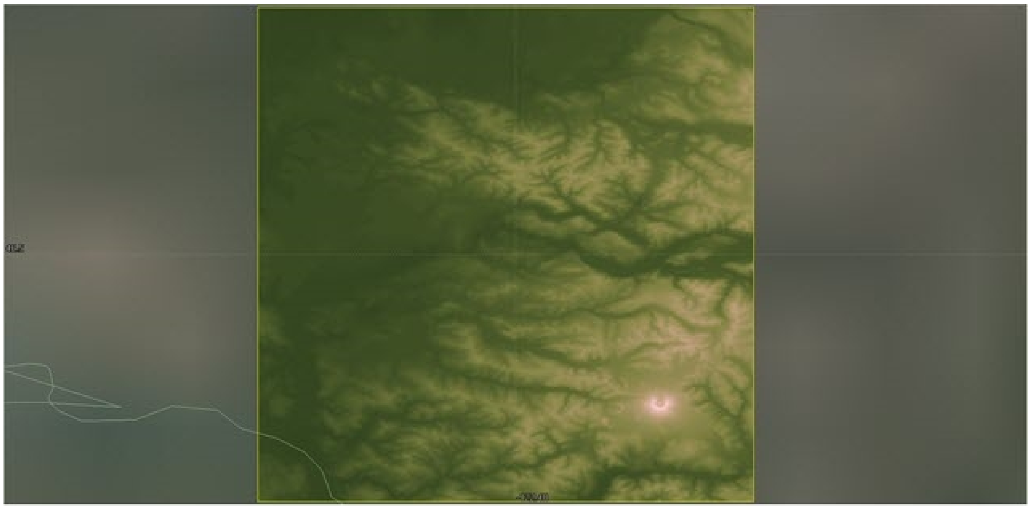
8. Click the Directory: ellipses button and browse to the location of your scenario (e.g. C:\Users\username\Documents\STK 12\STK_Pro).
9. Change Filename: to "StHelensColor".
10. Click Convert.
11. Close the Create Color Elevation Imagery utility.

2D Graphics Imagery

2D Graphics Imagery is used to display a background image and inlay images in 2D Graphics windows.

1. Bring the 2D Graphics window to the front.
2. Open the 2D Graphics window properties ().
3. On the Imagery page, locate the Inlay Images field and click the Add button.
4. Select the file StHelensColor.jp2.
5. Click Open.
6. Click OK.

Lower elevations are darker in color and higher elevations are lighter in color. Mount St. Helens sticks out as the highest point in the image.



COLOR ELEVATION IMAGE

Imagery and Terrain Converter

Use the Imagery and Terrain converter to convert a single image, with or without terrain data, into a format that can be displayed in a 3D Graphics window. The image is converted to a pdttx or jp2 file (image inlay) and the terrain data is converted to a pdtt file (terrain inlay).

Imagery

Convert an ISS SERVIR Environmental Research and Visualization System (ISERV) LEVEL-R (RAW) imagery .jpg into JPEG 2000 Image (jp2) inlay.

1. Open the Utilities menu and select Imagery and Terrain Converter.
2. In the Input Data field, click the Image Filename: ellipses button.
3. Browse to the location of the ISERV imagery. (Typically, <STK install folder>\Data\Resources\stktraining\imagery\)
4. Open the folder named ISERV_Imagery.

5. Select the file named IPR201407092040194622N12217W.JPG and click Open. The extents are automatically read from the metadata contained in the supporting files.

6. In the Output Data field, make the following Image File changes:

Option	Value
Format:	JPEG 2000 Image (jp2)
Directory:	Location of the scenario (e.g. C:\Users\username\Documents\STK 12\STK_ Pro
Filename:	ISERV_StHelens

7. Click Convert.

Terrain

Convert the hoquiam-e.dem file into a STK Terrain File (pdtt).

1. In the Imagery and Terrain Converter, select the Terrain Region page.

2. In the Input Data field, open the Terrain Source: pull down menu.

3. Select the path to the hoquiam-e.dem file.

4. In the Output Data field, make the following changes:

Option	Value
Directory:	Location of the scenario (e.g. C:\Users\username\Documents\STK 12\STK_ Pro
Filename:	StHelensTerrain

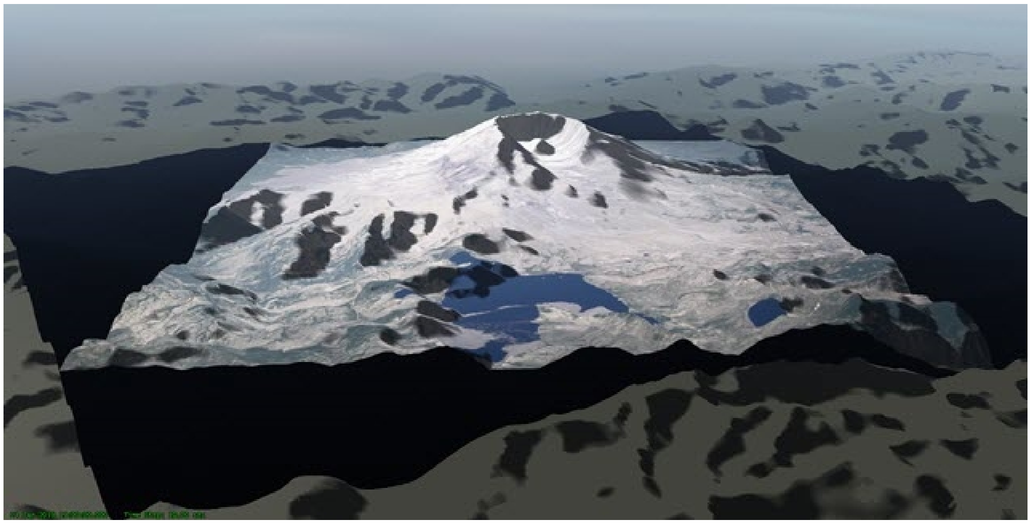
5. Click Convert.

6. Close the Imagery and Terrain Converter.

Globe Manager

Globe Manager allows you to customize scenario globes with imagery and terrain data as well as manage that data once it has been applied. The Hierarchy window is used to add central bodies, image and terrain items to a scenario.

1. Bring the 3D Graphics window to the front.
2. In the 3D Graphics window toolbar, click the Globe Manager ( ) icon. Globe Manager is docked below the Object Browser.
3. In the Hierarchy toolbar, click the Add Terrain/Imagery ( ) icon.
4. When the pop up window appears, select Add Terrain/Imagery.
5. When the Globe Manager: Open Terrain and Imagery Data window opens, ensure Local Files is selected.
6. Open the Path: pull down menu and select the path to your scenario (e.g. C:\Users\username\Documents\STK 12\STK_Pro).
7. Select both the Image (ISERV_StHelens.jp2) and Terrain files (StHelensTerrain.pdtt).
8. Click Add.
9. When the Use Terrain for Analysis window appears, select No. You're already using the hoquiam-e.dem file for analysis.
10. In Globe Manager, right-click on ISERV_StHelens.jp2 and select Zoom To.
11. Use your mouse to view the image and surrounding terrain.



ISERV IMAGERY ON TOP OF PDTT FILE.

You can see the satellite image ISERV_StHelens.jp2 which is placed on top of the StHelensTerrain.pdtt. Terrain outside of the image is still visible. If desired, you can return to Globe Manager and turn Aerial.ve back on to use Bing Maps. You can also, toggle ISERV_StHelens.jp2 or StHelensTerrain.pdtt on and off to see the visual difference. The ISERV_StHelens.jp2 image can also be used as an inlay in the 2D Graphics window.

12. When finished, ensure the ISERV_StHelens.jp2 and StHelensTerrain.pdtt are turned on.

Insert the GPS Tracking Device

Insert a Place ( ) object which will simulate the GPS satellite tracking device.

1. Using the Insert STK Objects Tool ( ) insert a Place ( ) object using the Insert Default ( ) method.
2. In the Object Browser, name the Place ( ) object "TrackingDevice".
3. Open TrackingDevice's ( ) properties ( ).
4. On the Basic - Position page, set the following:

Option	Value
Latitude:	46.204 deg
Longitude:	-122.188 deg

5. The tracking device is on a stand and is five (5) feet above the terrain. Set Height Above Ground: to 5 ft.
6. Click Apply.

Define an Azimuth-Elevation Mask

The AzElMask properties enable you to define an **azimuth-elevation mask** for the GPS tracking device.

1. Select the Basic - AzElMask page and set the following:

Option	Value
Use:	Terrain Data
Use Mask for Access Constraint	Enable

2. Click Apply.

Selecting Terrain Data automatically creates and stores an **azimuth-elevation (Az-El) mask file**, which is an ASCII text file that is formatted for compatibility with STK and ends in an .aem extension, into your scenario folder. Turning on Use Mask for Access Constraint enables the Az-El Mask constraint located on the **Constraints - Basic page**. Using the Az - El Mask constraint constrains access to the object by azimuth-elevation masking which is a 360 degree field of view around the object being constrained.

Display the Azimuth-Elevation Mask

For situational awareness, you can **display the Azimuth-Elevation Mask** in both the 2D Graphics and 3D Graphics windows.

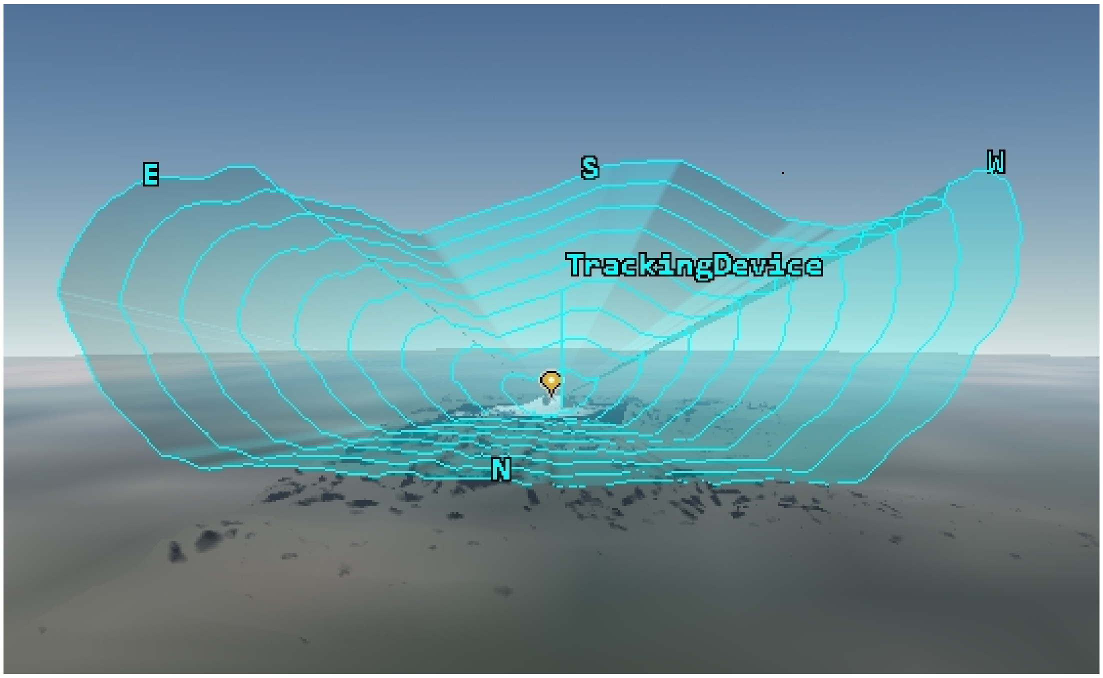
1. Select the 2D Graphics - AzElMask page and set the following At Range properties:

Option	Value
Show	Enabled
Number of Steps:	10
Minimum Range:	0
Maximum Range:	50 km

2. Click OK.
3. Bring the 3D Graphics window to the front.
4. Open the 3D Graphics window's properties ().
5. On the Details page, turn on Label Declutter - Enable.
6. Click OK.

   Label Declutter is used to separate the labels on objects that are in close proximity for better identification in small areas. It also keeps object labels from being hidden by terrain.

7. Right-click on TrackingDevice ( ) in the Object Browser and select Zoom To.
8. Using your mouse, zoom out until you can see the visual representation of the Azimuth-Elevation Mask.



AZ EL MASK

Each ring represents a ten (5) kilometer range out to fifty (50) kilometers. Around the edge of the view, you can see indications of North (N), South (S), East (E), and West (W). The view indicates that the view to the east, west, and south are poor. Visibility to the north is good.

Constellation Objects

Use the Insert STK Objects tool to load the GPS Constellation using orbital elements from GPS almanac files. The Almanac files can be stored in local directories or pulled from AGI Servers (internet connection required). STK creates a constellation that includes all of the satellites in the almanac. Keep in mind, you can build Constellation ( ) objects yourself by loading an empty Constellation ( ) object and assigning objects required for your analysis.

1. Using the Insert STK Objects Tool ( ) insert a Satellite ( ) object using the Load GPS Constellation ( ) method.

   Once loaded, you will see each individual Satellite ( ) object and a Constellation ( ) object containing all of the satellites.

2. Open GPSConstellation's ( ) properties ( ).

   On the Basic - Definition page, you can see each GPS satellite has been moved to the Assigned Objects list. If required, you could remove any satellites from the list that are down or are not required for analysis.

3. Select the Constraints - Basic page.

   For the purposes of this problem, you require access to at least four (4) GPS satellites at any given time. It doesn't matter which four. Also, take into account that when performing an access, the access will be analyzed from the satellite to the GPS tracing device.

4. In the Logical Restriction field, set 'From' access position: to At Least N and the value to 4.

5. Click OK.

Chain Objects

A **Chain** object is a list of objects (either individual or grouped into constellations) in order of access.

1. Using the Insert STK Objects Tool ( ) insert a Chain ( ) object using the Define Properties ( ) method.

2. On the Basic - Definition page, move ( ) GPSConstellation from the Available Objects list to the Assigned Objects list.

3. Next, move ( ) TrackingDevice from the Available Objects list to the Assigned Objects list.

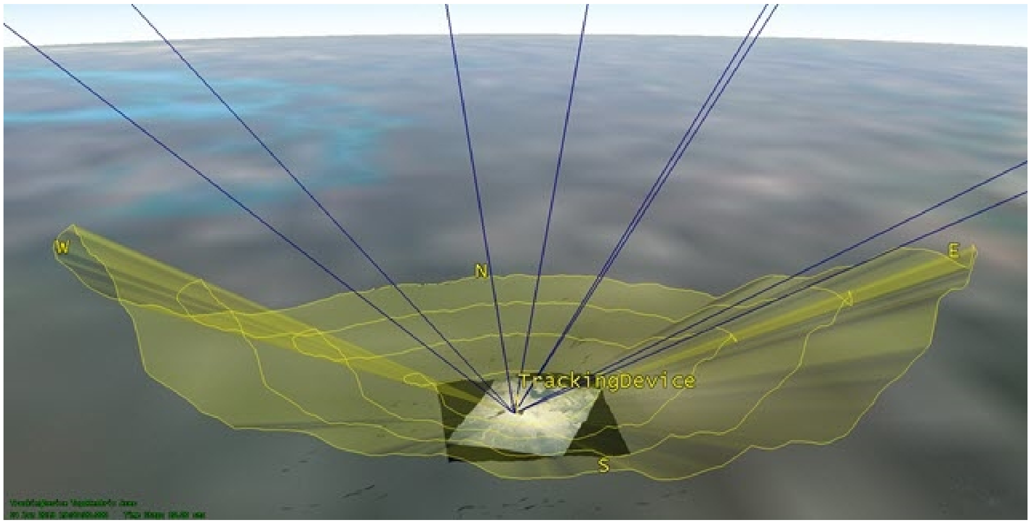
4. Click OK.

5. In the Object Browser, rename the Chain ( ) object "GPStoDevice".

6. Bring the 3D Graphics window to the front.

7. Zoom To TrackingDevice.

8. Using your mouse, zoom out until you can see accesses from the ground site to the GPS satellites.



CHAIN ACCESSES

9. Click the Start ( ) icon in the Animation Toolbar and animate the scenario. Notice how the accesses don't appear until they're above the Az El Mask. Conversely, they disappear when they reach the Az El Mask. Terrain is being taken into account for the accesses.

10. When finished, Reset ( ) the animation.

Complete Chain Access

The **Complete Chain Access** report shows times during which access among all objects in a chain is possible through one or more strands. Analyze a complete chain access.

1. In the Object Browser, right-click on GPStoDevice ( ) and select the Report & Graph Manager.

2. When the Report & Graph Manager opens, go to the top of the Styles list and turn off Show Reports.

3. In the Styles list, select the Complete Chain Access graph and click the Generate button.

   The Complete Chain Access graph might seem boring, but it's telling you exactly what you need to know. If there is a solid line across the report, that means you always have access to at least four (4) or more GPS satellites during the entire analytical period. If there is a break in the line, that's a period when three (3) or less GPS satellites are being accessed.

4. Close the Graph.

Individual Strand Access

A **Individual Strand Access** report represents one possible access pathway through the chain. For a chain that consists of a series of individual objects, only a single strand is possible. If a chain contains one or more constellations, multiple strands are possible, but constellation constraints (ANY OF, ALL OF, AT LEAST N, EXACTLY N) can affect the possible number of strands.

1. Return to the Report & Graph Manager.
2. In the Styles list, select the Individual Strand Access graph and click the Generate button.
3. This graph shows you when the ground site can see individual GPS satellites when that satellite is paired up with at least three more satellites.
4. Keep the graph open.
5. Open TrackingDevice's ( ) properties ( ).
6. Select the Constraints - Basic page.
7. Turn off Az-El Mask.
8. Click Apply.
9. Return to the Individual Strand Access graph and refresh ( ) the graph.

   Notice how the individual strands grow larger, because the surrounding terrain is no longer being used in the analysis.
10. Return to TrackingDevice's ( ) properties ( ).
11. Turn Az-El Mask back on.

12. Click OK.

13. Return to the Individual Strand Access graph and refresh () the graph.

The individual strands shrink because analytical terrain is being used in the analysis.

Save Your Work

1. When finished, Reset () the scenario and close any reports or tools that are still open.

2. Save () your work.

On Your Own

Should you use AzEl Mask or Terrain Mask? Make sure to read the PROs and CONs between the two. When using a Facility, Place or Target object in an access computation, obscuration of the line of sight by terrain can be accounted for in one of two ways: selection of the Terrain Mask constraint or selection of the AzEl Mask constraint. While both constraints serve to model the same physical obstruction, there are important differences between the constraints which should be considered when selecting between the two. Try using Terrain Mask instead of Az-El Mask as a constraint and compare the differences in your reports or graphs and the difference in calculation time.

Also, you could enable Terrain Server and enable either Line-Of-Sight Terrain Mask or Azimuth/Elevation Mask. Place a ground site anywhere on the globe and access a satellite of your choice. Make sure to tell the ground site to use terrain. Try accessing a Ground Vehicle () object or an Aircraft () object as it moves through terrain. Have fun!

Part 7: Customize Analysis with Analysis Workbench

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- Analysis Workbench

Problem Statement

Engineers and technicians require additional capabilities when using STK to create custom functions and calculations relative to times, positions, and reference frames. You work at a ground station that tracks a recently launched satellite. The ground station's sensor must be turned off when its boresight is within 10 degrees of the Sun. You need a report that tells you when it's safe to track the satellite.

Solution

Use a combination of STK Pro and STK's *Analysis Workbench* capability to create vectors, custom angles, calculations, time components and temporal constraints to determine when the sensor can safely track the satellite.

What You Will Learn

Upon completion of this tutorial, you will understand the following ***Analysis Workbench* Tools**:

- **Vector Geometry Tool**
- **Time Tool**
- **Calculation Tool**

Video Guidance

Create a New Scenario

Create a new scenario.

1. Launch STK ( ).
2. Click Create a Scenario ( ).
3. Enter the following in the New Scenario Wizard:

Option	Value
Name:	STK_AnalysisWorkbench
Location:	Default
Start:	1 Mar 2021 16:00:00.000 UTCG
Stop:	+ 2 days

4. Click OK when you finish.
5. Click Save ( ) when the scenario loads. A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location.
7. Click Save .

Note: Save Often!

Disable Terrain Server

Terrain is not required for this analysis. Disable the **Terrain Server**.

1. Right- click on STK_AnalysisWorkbench ( ) in the Object Browser.
2. Select Properties ( ).
3. Select the Basic - Terrain page.
4. Clear the Use terrain server for analysis check box.
5. Click OK to accept the changes and close the Properties Browser.

Satellite Tracking Station

Insert a **Facility object** which will act as a satellite tracking station.

1. Select Facility ( ) in the Insert STK Objects tool.
2. Select the Insert Default ( ) method.
3. Click **Insert...** .
4. Right-click on Facility1 ( ) in the Object Browser.
5. Select Rename.
6. Rename Facility1 ( ) Tracking_Station.

Recently Launched Satellite

Insert a **Satellite object** which will be tracked by the tracking station.

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the Orbit Wizard ( ) method.
3. Click **Insert...** .
4. Set the following in the Orbit Wizard:

Option	Value
Type:	Circular
Satellite Name:	New_Sat

Inclination:	50 deg
Altitude:	800 km
RAAN:	-85 deg

5. Click OK .

Calculate Access

Calculate the times the tracking station can access or see the satellite using the **Access tool**. This access will be used as a component when using the *Analysis Workbench*.

1. Right-click on Tracking_Station ( ) in the Object Browser.
2. Select Access ( ).
3. Select New_Sat ( ) in the Access Tool's Associated Objects list.
4. Click Compute (Compute).
5. Look at the Timeline View. By default the Timeline View is docked at the bottom of the STK GUI.
6. Note the multiple accesses between Tracking_Station ( ) and New_Sat ( ).
7. Click Close to close the Access tool.

Vector Geometry Tool

The **Vector Geometry Tool** (VGT) offers the ability to build custom geometric models from any combination of out-of-the box or user-created Vector ( ), Axes ( ), Point ( ), System ( ), Angle ( ) and Plane ( ) components.

Open Tracking Station's Properties

Open Tracking_Station's ( ) 3D Graphics - Vector Properties page. We will select vectors to display in the 3D Graphics window.

1. Open Tracking_Station's ( ) properties ( ).
2. Select the 3D Graphics - Vector page.
3. Select the Vectors tab.

Display Sun Vector

Display the **Sun Vector.** In this scenario, the Sun Vector is anchored to tracking station's center point and targets the Sun.

1. Select the Sun Vector Show check box.
2. Click **Apply** to accept the changes and keep the Properties Browser open.

Show Sun Vector

View the Sun Vector in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.
2. Right-click on Tracking_Station ( ) in the Object Browser.
3. Select Zoom To.
4. Zoom out far enough so that you can see the Sun vector.
5. Click Start ( ) to animate the scenario in the Animation toolbar. The Sun Vector follows the Sun.
6. Click the Reset ( ) when you are finished.

Show To Vector

A To Vector is a displacement vector between origin and destination object points. To Vectors are automatically generated by STK for all objects in your scenario. The vectors are stored in a separate folder labeled, To Vectors, unless a vector with the same name already exists (Earth or Sun). In scenarios with many objects, the To Vectors folder can be very large for each object. View the New_Sat's ( ) To Vector.

1. Return to Tracking_Station's ( ) 3D Graphics - Vector properties ( ) page.
2. Select the Vectors tab.
3. Click **Add...** .
4. Click the Expand (⊞) button beside To Vectors ( ) in the Components for: list on the right of the Add Components window.
5. Select New_Sat.
6. Click **OK** to close the Add Components window.

Show Magnitude

If Show Magnitude is selected, the magnitude value is displayed on the selected vector. This is only available for vectors ( ). Show the magnitude for New_Sat's ( ) To Vector.

1. Return to Tracking_Station's ( ) properties ( ) .
2. Ensure New_Sat Vector is selected in the Vectors list on the 3D Graphics - Vector page.
3. Select Show Magnitude.
4. Click **Apply** .

View To Vector

View the To Vector and the Magnitude in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.
2. Click Start ( ) in the Animation toolbar to animate the scenario.

   The New_Sat Vector may be below the surface of the central body because the satellite is below the horizon but will eventually surface. The vector follows the satellite. Show Magnitude provides a constant distance between the tracking station and the satellite, dynamically, in the 3D Graphics window.

3. Click the Reset () when you are finished.

Create a Custom Angle

Create an angle ( ) between the Sun Vector and the New_Sat To Vector. For the purposes of this scenario, whenever the angle is 10 degrees or less, the satellite tracking system needs to be shut down.

Open Analysis Workbench Tools

Open the *Analysis Workbench* Tools, and select the Vector Geometry tab.

1. Right-click on Tracking_Station () in the Object Browser.
2. Select *Analysis Workbench* ().
3. Select the Vector Geometry tab.
4. Ensure Tracking_Station () is selected in the Object list.
5. Click Create new Angle ( ) to open the Add Geometry Component window.

Create a Between Vectors Angle

Select the Between Vectors angle type. You will create an angle between the Sun Vector and the New_Sat Vector.

1. Ensure the Type: is set to Between Vectors. This is the default Type.

2. Enter TrackingAngle in the Name: field.

Select the From Vector

Select New_Sat's ( ) To Vector as the From Vector. The custom angle, TrackingAngle, will be measured starting from New_Sat's To Vector.

1. Click the ellipsis button ( ) beside the From Vector: field. The Select Reference Vector window opens.

2. Select Tracking_Station ( ) in the Objects list.

3. Scroll up in the Vectors for: Tracking_Station list on the right.

4. Click the Expand (⊞) button beside To Vectors ( ).

5. Select New_Sat.

6. Click **OK** to close the Select Reference Vector window.

Select the To Vector

Select the Sun Vector as the To Vector. The custom angle, TrackingAngle, will be measured between the New_Sat's To Vector and the Sun vector.

1. Return to the Select Reference Vector window.

2. Note that To Vector: already has the Tracking_Station Sun vector selected.

3. Click OK to close the Add Geometry Component window.
4. Note the TrackingAngle vector is in My Components ().
5. Keep the *Analysis Workbench* () open.

Display the Custom Angle

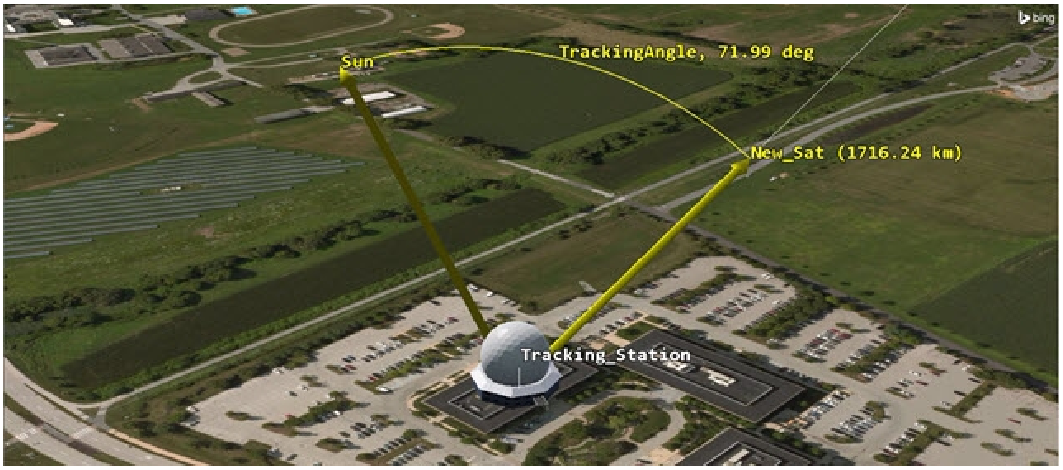
Custom angles can be viewed in the 3D Graphics window. Add the custom tracking angle to Tracking_Station's () 3D Graphics - Vector Properties page.

1. Return to Tracking_Station's () properties ().
2. Select the 3D Graphics - Vector page.
3. Select the Angles tab.
4. Click Add... .
5. Select TrackingAngle in the My Components () folder in the the Components for: list.
6. Click OK to close the Add Components window.
7. Note Show is selected for TrackingAngle.
8. Click OK to accept the changes and close the Properties Browser.

View Tracking Angle

View the tracking angle in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.



VECTORS AND ANGLE VIEW

2. Click Start ( ) in the Animation toolbar to animate the scenario.

3. Note as the scenario animates, the angle increases and decreases, updating dynamically.

4. Click the Reset () when you are finished.

Calculation Tool

The **Calculation Tool** includes components of the following basic types: Scalar (), Condition ( ) and Parameter Set ( ). Use the Calculation Tool to determine when the tracking angle is 10 degrees or less.

Scalar

Create a Scalar to return the tracking angle values. A scalar defines components that produce scalar time-varying calculations. Scalar calculation components also have the ability to return minimum, maximum, mean, and standard deviation values.

Create a Scalar

Start by creating a new Scalar Calculation ( ).

1. Return to the *Analysis Workbench* ( ).
2. Select the Calculation tab to open the Calculation Tool.
3. Select Tracking_Station ( ) in the Object list.
4. Click Create new Scalar Calculation ( ) to open the Add Calculation Component window.

Define Scalar Calculation

The default scalar calculation type is Angle. The Angle type is an angular displacement specified by an Angle component from the Vector Geometry Tool.

1. Ensure the Type: is set to Angle. This is the default Type.
2. Enter Scalar_TrackingAngle in the Name: field.
3. Click the ellipsis ( ) beside the Input Angle: field. The Select Reference Angle window opens.
4. Select Tracking_Station ( ) in the Objects list.
5. Select TrackingAngle in the My Components ( ) folder in the Angles for: Tracking_Station list.
6. Click OK to close the Select Reference Vector window.
7. Click OK to close the Add Calculation Component window.
8. Note Scalar_TrackingAngle is in My Components ( ).

Condition

Conditions define a scalar calculation which is considered to be satisfied when it is positive and not satisfied when it is negative. Create a Condition ( ) to report when the tracking angle is 10 degrees or less.

Create a Condition

Create a new Condition ( ).

1. Return to the *Analysis Workbench* ( ) Calculation tab.
2. Select Tracking_Station ( ) in the Object list.
3. Click Create new Condition ( ) to open the Add Calculation Component window.

Define Calculation Condition Type

The default Calculation type is Scalar Bounds. Scalar Bounds defines a condition by combining a specified Scalar component with scalar bounds.

1. Ensure the Type: is set to Scalar Bounds. This is the default Scalar Bounds.
2. Enter Below_10_Degrees in the Name: field.

Define the Scalar

Set the Scalar Calculation, Scalar_TrackingAngle, as the Reference Scalar Calculation.

1. Click the ellipsis ( ) beside the Scalar: field. The Select Reference Scalar Calculation window opens.
2. Select Tracking_Station ( ) in the Objects list.

3. Select Scalar_TrackingAngle in the My Components ( ) folder in the Scalar_TrackingAngle for: Tracking_Station list.

4. Click **OK** to close the Select Reference Scalar Calculation window.

Define the Calculation Conditions

Define the calculation conditions.

1. Select Below Maximum in the Operation drop down list.

2. Enter 10 deg in the Maximum: field.

3. Click **OK** to close the Add Calculation Component window.

Create a Report

You can create reports and graphs directly inside the Calculation Tool. Create a report showing when the tracking angle is below 10 degrees.

1. Return to the *Analysis Workbench* ( ) Calculation tab.

2. Select Tracking_Station ( ) in the Objects list.

3. Expand (⊞) Below_10_Degrees in the My Components ( ) Components for: list.

4. Right-click on SatisfactionIntervals.

5. Select Report.

   The report shows when the tracking angle is 10 degrees or less during the entire scenario interval. However, it doesn't restrict the report to those times when there are accesses between the tracking station and the satellite.

6. Close ( ) the report.

7. Keep the *Analysis Workbench* ( ) open.

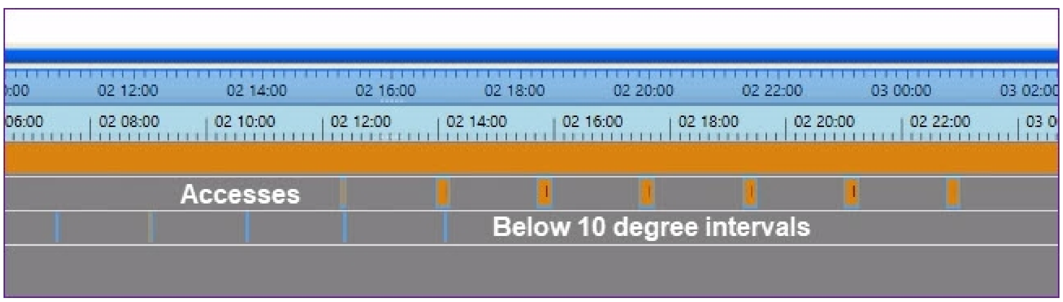
View Accesses and Satisfaction Intervals in the Timeline View

The **Timeline View** can be used to visualize a variety of time intervals within your scenario. Use the Timeline View to visualize the times Tracking_Station ( ) has access to New_Sat ( ) and the times the tracking angle is less than 10 degrees.

1. Return to the *Analysis Workbench* ( ).

2. Select SatisfactionIntervals under Below_10_Degrees in the My Components ( ) Components for: list.

3. Drag and drop SatisfactionIntervals into the Timeline View's Time Display.



ACCESSES AND BELOW 10 DEGREE SATISFACTION INTERVALS

4. Observe the Timeline View.

   Can you see any times when the tracking angle is below 10 degrees and might interrupt accesses?

Time Tool

Use the **Time Tool** to create and manage any time instant( ), interval ( ), interval list ( ), collection of interval lists ( ) or time array ( ). Create an interval list to show when Tracking_Station ( ) has access to New_Sat ( ) while the tracking angle is above 10 degrees.

Create an Interval List

Create a custom Interval List ( ) by merging access times and the below 10 degree satisfaction intervals. Subtract the below 10 degree satisfaction intervals from the accesses to define tracking opportunities.

1. Return to the *Analysis Workbench* ( ).
2. Select the Time tab.
3. Select Tracking_Station ( ) in the Object list.
4. Click Create new Interval List ( ) to open the Add Time Component window.
5. Enter Optimal_Tracking_Times in the Name: field.

Define the Interval List Type

Create a Merged Interval List. Merged Interval Lists are intervals merged from multiple Interval or Interval List Time Components using a merge operation.

1. Click **Select...** beside the Type: field.
2. Select Merged ( ) in the Select Component Type window list.
3. Click **OK** to close the Select Component Type window.

Define the Operation

Define the merge operation as Minus. Subtract the below 10 degree satisfaction intervals from the accesses to define tracking opportunities. The Minus operation is available when there are only two Time Components in the merge list.

1. Return to the Add Time Component window.
2. Select MINUS in the Operation drop down list.

Remove Time Components

Remove default time components.

1. Select the first time component in the Time Components: list.
2. Click **Remove** .
3. Repeat the above steps until all time components are removed.

Define the Time Components

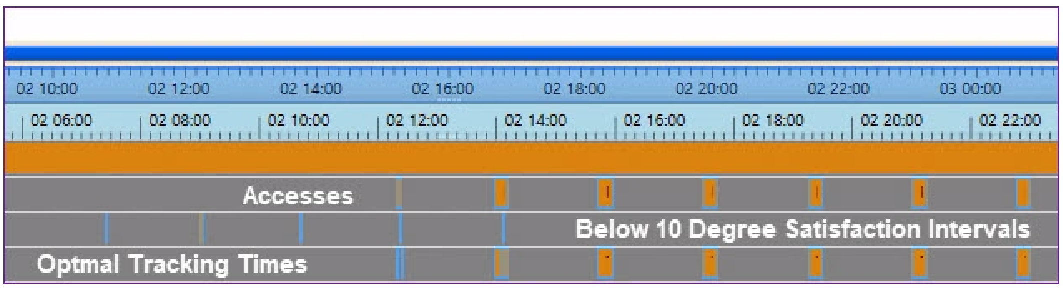
In this instance, there are two time components: the accesses between the tracking station and the satellite and the below 10 degree satisfaction intervals.

1. Click **Add...** to open the Select Time Intervals window.
2. Select Facility-Tracking_Station-To-Satellite-New_Sat ( ) in the Object list.
3. Select AccessIntervals in the Installed Components ( ) Components for: list.
4. Click **OK** to close the Select Time Intervals window.
5. Click **Add...** on the Add Time Component window.
6. Select Tracking_Station ( ) in the Object list.
7. Expand (⊞) Below_10_Degrees in the My Components ( ) Components for: list.
8. Select SatisfactionIntervals.
9. Click **OK** to close the Select Time Intervals window.
10. Click **OK** to close the Add Time Component window.

View Intervals in the Timeline View

You now have all the components for your analysis completed. View them in the Timeline View.

1. Return to the *Analysis Workbench* ( ) Time tab.
2. Select Optimal_Tracking_Times in the My Components ( ) Components for: list.
3. Drag and drop Optimal_Tracking_Times into the Timeline View's Time Display.



TIMELINE VIEW SHOWING ALL TIME COMPONENTS

4. Observe the Timeline View to see the merged intervals.
5. Return to the *Analysis Workbench* ( ).
6. Click **Close** .

Tracking Station Sensor

Attach a Sensor object ( ) to the tracking station to track the satellite. Then, using the custom components created in this lesson, model an outage on the sensor when the tracking angle goes below 10 degrees.

Insert a Sensor on Tracking Station

Insert a sensor object on the tracking station.

1. Select Sensor ( ) in the Insert STK Objects tool.
2. Select the Define Properties ( ) method.
3. Click Insert... .
4. Select Tracking_Station ( ) on the Select Object window.
5. Click OK .

Model Limited Field-of-View

Set a limited field of view for the sensor to provide situational awareness.

1. Select the Basic - Definition page.
2. Ensure the Sensor Type: is set to Simple Conic. This is the default type.
3. Enter 2 deg in the Cone Half Angle: field.
4. Click Apply .

Target the Sensor

Use the Targeted pointing type to point the sensor at the satellite.

1. Select the Basic - Pointing page.
2. Select Targeted in the Pointing Type: drop down list.
3. Select New_Sat ( ) in the Available Targets list.
4. Click Move ( ) to move New_Sat ( ) to the Assigned Objects list.
5. Click OK .
6. Rename Sensor1 ( ) Tracking_Sensor.

Calculate Access

Compute an access between the sensor () and the satellite ().

1. Right-click on Tracking_Sensor () in the Object Browser.
2. Select Access ().
3. Select New_Sat () in the Access Tool's Associated Objects list.
4. Click Compute (Compute).
5. Click Access... in the Reports section.
6. Note the multiple accesses between Tracking_Station () and New_Sat ().
7. Keep the Access tool () and the report open.

Add Temporal Constraints

You want to know when the tracking station's sensor accesses the satellite, but restrict access when the sensor's boresight is within 10 degrees of the Sun. You can do this by adding a **Temporal Constraint** to your sensor object using the custom components created earlier in this lesson.

1. Open Tracking_Sensor's () properties ().
2. Select the Constraints - Temporal page.
3. Select Use in the Intervals section.
4. Click Import... to open the Select Time Intervals window.
5. Select Tracking_Station () in the Object list.

6. Select Optimal_Tracking_Times in the My Components ( ) Components for: list.

7. Click OK to close the Select Time Intervals window.

8. Note the intervals have populated in the Intervals list.

9. Click OK to close the Properties Browser.

Create a New Access Report

Create a new access report to compare the original access report with the constrained report.

1. Return to the Access tool ( ).

2. Click Access... in the Reports section.

3. Compare your original access report's Total Duration with the constrained access report's Total Duration.

4. Note the temporal constraint shortens your access time.

5. Note the times in the access report are the times your sensor can safely access the satellite.

```
Global Statistics
-----------------
Min Duration          7    2 Mar 2021 12:21:15.414    2 Mar 2021 12:21:43.904          28.491
Max Duration         13    2 Mar 2021 20:59:14.485    2 Mar 2021 21:15:20.993         966.507
Mean Duration                                                                         682.829
Total Duration                                 Temporal Constraint Total Duration   12290.931

Global Statistics
-----------------
Min Duration         13    3 Mar 2021 11:48:10.294    3 Mar 2021 11:51:00.314         170.020
Max Duration         11    2 Mar 2021 20:59:14.481    2 Mar 2021 21:15:20.988         966.507
Mean Duration                                                                         837.652
Total Duration                                       Unconstrained Total Duration   12564.774
```

TEMPORAL CONSTRAINT TOTAL DURATION COMPARISON

Solar Exclusion Angle

What you have built and used in this lesson is a Solar Exclusion Angle. Set that directly in the sensor constraints.

1. Open TrackingSensor's ( ) properties ( ).
2. Select the Constraints - Temporal page.
3. Disable the Use option in the Intervals list.
4. Select the Constraints - Sun page.
5. Enable the Boresight - Solar Exclusion Angle.
6. Set the value to ten (10) deg.
7. Click OK to close the Properties Browser.

The access times update and just like before, you can see the times that your sensor can safely access the satellite.

Save Your Work

1. Close any open reports, properties and tools which are still open.
2. Save ( ) your work.

Summary

This tutorial focused on three tools that are available in the *Analysis Workbench*:

1. Vector Geometry Tool
2. Time Tool
3. Calculation Tool

In this lesson:

1. You inserted a tracking station and a low earth orbit (LEO) satellite.
2. Created an access between the tracking station and the satellite.
3. Displayed the tracking station's Sun and satellite's To Vector in the 3D Graphics window.
4. Used the Vector Geometry tool to create a custom angle between the vectors.
5. Used the Calculation tool to create a scalar using the tracking angle and then a condition which reported when the angle was 10 degrees or less.
6. Used the Time tool to create an interval list by merging the access intervals with the below 10 degrees satisfaction intervals. Subtracting the below 10 degrees satisfaction intervals from the access intervals created the optimal tracking times for your system.
7. Attached a sensor to the tracking station and targeted the sensor to the satellite.
8. Created a constrained interval by importing the optimal tracking times into the sensor's properties. This caused the Access tool to only report accesses during the optimal tracking times. The final report can be used to know when it is safe to tracking the satellite with the sensor.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information. Now's a good time to go back through this tutorial and view that information.

Further training using the *Analysis Workbench*:

- STK Training: Look at the License Required column. All lessons with AWB are lessons which use the *Analysis Workbench*.

Part 8: Compute Coverage Over Regions

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro
- Coverage

Problem statement

Engineers and operators need to analyze global or regional coverage from one asset or from a collection of assets. Constraints, such as sunlight and terrain, might need to be taken into account. They may need to simply analyze if a sensor footprint passes over a specific ground location. Or, they may need to analyze a large area of ground or space and determine communication bit error rates in the area of interest, age of data, dilution of precision, etc. In this lesson, three satellites and their sensor footprints will be analyzed on the Earth's surface. You need to determine what percentage of the Earth's surface is seen by all three sensors during a 24 hour period while taking into consideration sunlight, umbra and how many times points on the ground are accessed. Then, you need to determine how long one satellite sensor covers Canada and the continental United States during the same 24 hour period.

Solution

Use STK to model Earth observing payloads attached to sensors located in three different orbits. Use STK's ***Coverage*** capability to model and analyze the quality and quantity of coverage provided by the three payloads. Determine:

1. The percentage of the Earth's surface the satellite payloads survey during a 24 hour period and daylight hours only.
2. How many times the satellite payloads survey points on the ground during a 24 hour period and daylight hours only.
3. How long points on the ground are seen in Canada and the continental United States.

What you will learn

Upon completion of this tutorial, you will be able to:

- Compute global coverage
- Compute coverage in designated areas
- Understand a coverage grid
- Use constraints in a coverage grid
- Determine coverage assets
- Choose which data providers supply answers to your questions
- Create color contours pertaining to the coverage analysis in the 2D and 3D Graphics windows

Create a New Scenario

Create a new scenario.

1. Launch STK ( ).
2. Click Create a Scenario ( ) in the Welcome to STK window.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	STK_Coverage
Location:	Default
Start:	1 Jul 2020 16:00:00.000 UTCG
Stop:	2 Jul 2020 16:00:00.000 UTCG

4. Click **OK** when you finish.
5. Click Save ( ) when the scenario loads. A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location.
7. Click **Save** .

Note: Save Often!

View Both the 2D and 3D Graphics Windows

You can view coverage in both the 2D and 3D Graphics windows. Placing them side by side makes this simple to do.

1. Close ( ) the Timeline View at the bottom of STK.
2. Extend the Window menu.
3. Select Tile Vertically to evenly space the windows side-by-side in the integrated workspace.

Turn Off Terrain Server

Analytical and visual terrain is not required in this analysis. Let's turn off the Terrain Server.

1. Right-click on STK_Coverage ( ) in the Object Browser.
2. Select Properties ( ).
3. Select the Basic - Terrain page.
4. Clear Use terrain server for analysis.
5. Click OK to accept the changes and close the Properties Browser..

Circular Satellite Orbit

Insert the first Satellite ( ) and place it in a circular orbit. Circular orbits have a constant radius.

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the Orbit Wizard ( ) method.
3. Click Insert... .
4. Set the following in the Orbit Wizard window:

Option	Value
Type:	Circular
Satellite Name:	Circ_Sat
Inclination:	55 deg
Altitude:	700 km

5. Click OK .

Repeating Ground Trace Satellite Orbit

Insert the second Satellite ( ) and place it in a repeating ground trace orbit. Orbits with repeating ground traces are useful when identical viewing conditions are desired at different times to detect changes. The ground trace may be caused to repeat every day or to interweave from day to day before repeating.

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the Orbit Wizard ( ) method.
3. Click Insert... .
4. Set the following in the Orbit Wizard window:

Option	Value

Type:	Repeating Ground Trace
Satellite Name:	Repeat_Sat

5. Click OK .

Sun Synchronous Satellite Orbit

Insert the third Satellite ( ) and place it in a sun synchronous orbit. These orbits are designed to utilize the effect of the Earth's oblateness, causing the orbit plane to precess at a rate equal to the mean orbital rate of the Earth around the Sun. Sun synchronous orbits have the property that their nodes maintain constant local mean solar times.

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the Orbit Wizard ( ) method.
3. Click Insert... .
4. Set the following in the Orbit Wizard window:

Option	Value
Type:	Sun Synchronous
Satellite Name:	Sun_Sat

5. Click OK .

Payloads

All three satellites use the same sensor type and size. STK allows you to copy and paste objects from one object to another. You will set up the first sensor, then copy and paste it to the other two. All you'll have to do is rename them or STK will use the same name with a one-up number.

Insert a Sensor

Insert a Sensor ( ) on Circ_Sat ( ). Define a **rectangular** sensor with a 20 deg vertical half-angle and 10 deg horizontal half-angle.

1. Select Sensor ( ) in the Insert STK Objects tool.
2. Select the Define Properties ( ) method.
3. Click **Insert...** .
4. Select Circ_Sat ( ) in the Select Object window.
5. Click **OK** .
6. Ensure the Basic - Definition page is selected.
7. Set the following:

Option	Value
Sensor Type:	Rectangular
Vertical Half Angle:	20 deg
Horizontal Half Angle:	10 deg

8. Click **OK** .

Reuse Sensor Objects

Copy and paste the rectangular sensor onto the other two satellites.

1. Select the Sensor ( ) attached to Circ_Sat ( ) in the Object Browser .
2. Click Copy ( ) in the Object Browser toolbar.
3. Select Repeat_Sat ( ) in the Object Browser.
4. Click Paste ( ) in the Object Browser toolbar.
5. Select Sun_Sat ( ) in the Object Browser.
6. Click Paste ( ) in the Object Browser toolbar
7. Expand ( ) Repeat_Sat ( ) and Sun_Sat ( ).

Rename the Sensor Objects

Rename the three sensors.

1. Right-click on the Sensor ( ) object attached to Circ_Sat ( ) in the Object Browser.
2. Select Rename.
3. Enter Circ_Sens.
4. Press Enter on your keyboard.
5. Repeat the steps above to rename Repeat_Sat's sensor ( ) Repeat_Sens and Sun_Sat's sensor ( ) Sun_Sen.

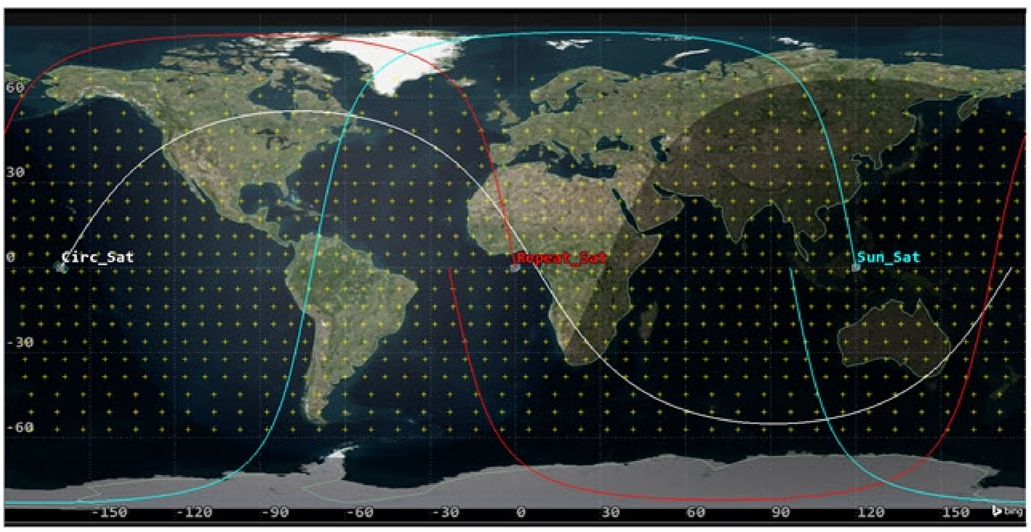
Coverage Definition Object

The **Coverage Definition object** defines a coverage area for analysis.

Insert Coverage Definition

Insert a Coverage Definition () into your scenario.

1. Select Coverage Definition () in the Insert STK Objects tool.
2. Select the Insert Default () method.
3. Click **Insert...** .
4. Right-click on CoverageDefinition1 () in the Object Browser.
5. Select Rename.
6. Enter World_Cov.
7. Press Enter on your keyboard.



2D GRAPHICS WINDOW DEFAULT COVERAGE GRID

The grid area of interest default setting is latitude bounds and covers 60 degrees south latitude to 70 degrees north latitude. The point granularity defaults to every 6 degrees and sits on the surface of the WGS84. You can determine the spacing between grid points using grid definition options. These options help you define the fineness or coarseness of the grid. The use of finer grid resolutions typically produce more accurate results, but requires additional computational time and resources.

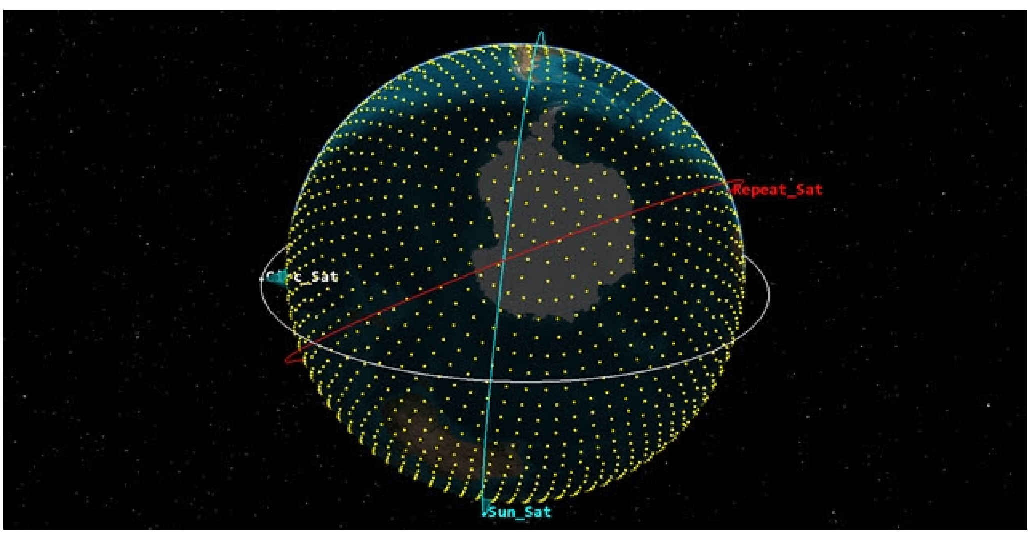
Define Coverage Grid

Define the coverage grid to be global with 4 degree point granularity.

1. Right-click on World_Cov' ( ) in the Object Browser.
2. Select Properties ( ).
3. Select the Basic - Grid page.
4. Set the following:

Option	Value
Type:	Global
Point Granularity - Lat/Lon:	4 deg

5. Click Apply .
6. Select the 2D Graphics window to bring it to the front. The grid now covers the entire Earth and the grid spacing is 4 degrees instead of 6 degrees.
7. Select the 3D Graphics window to bring it to the front. Notice the grid covers the entire globe and the grid spacing is 4 degrees.



Assign Coverage Assets

Assets properties allow you to specify the STK objects used to provide coverage. Define the three sensors as the Coverage Assets.

1. Return to World_Cov's ( ) properties ( ).
2. Select the Basic - Assets page.
3. Use the Ctrl key to select all three Sensor ( ) objects in the Assets field.
4. Click **Assign** .
5. Click **Apply** .

Automatically Recompute Accesses

STK automatically recomputes accesses every time an object on which the coverage definition depends (such as an asset) is updated. If you want control as to when coverage is computed, you need to turn this off.

1. Select the Basic - Advanced page.
2. Clear Automatically Recompute Accesses.
3. Click **OK** .

Compute Accesses Tool

The ultimate goal of coverage is to analyze accesses to an area using assigned assets and applying necessary limitations upon those accesses. Let's compute coverage with the Compute Accesses tool.

1. Select World_Cov ( ) in the Object Browser.
2. Extend the CoverageDefinition menu.

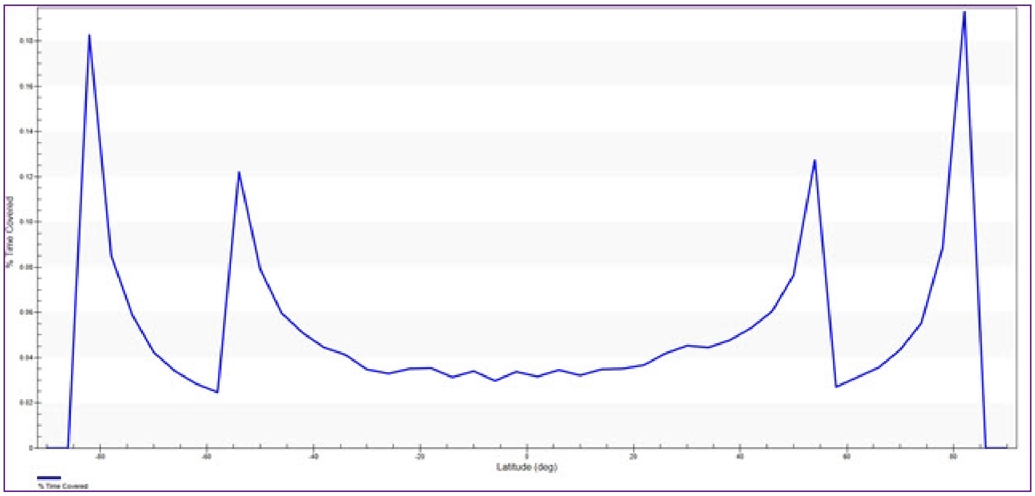
3. Select Compute Accesses. There is a progress bar in the lower right corner of STK.

4. Right-click World_Cov ( ) in the Object Browser when computing accesses is complete.

5. Select Report & Graph Manager ( ).

6. Select Coverage By Latitude graph ( ) in the Installed Styles list.

7. Click **Generate...** .



COVERAGE BY LATITUDE GRAPH

The Coverage By Latitude graph is a quick way to see the percentage of time covered by latitude.

8. Close ( ) the graph.

9. Click **Close** on the Report & Graph Manager window.

Figure of Merit

STK allows you to specify the method by which the quality of coverage is measured using a Figure Of Merit ( ) object.

Insert Figure of Merit

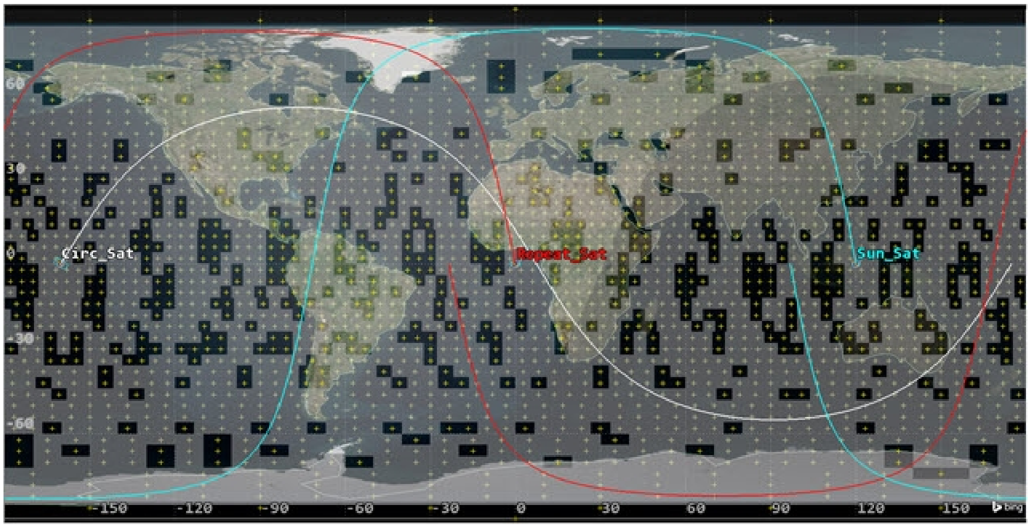
Insert a Figure of Merit.

1. Select Figure Of Merit ( ) in the Insert STK Objects tool.
2. Select the Insert Default ( ) method.
3. Click Insert... .
4. Select World_Cov ( ) in the Select Object window.
5. Click OK .
6. Rename the Figure Of Merit ( ) Simple_Cov.

Measure Simple Coverage

Simple Coverage measures whether or not a point is accessible by any of the assigned assets during the analysis period. Areas on the map that are shaded mean that the surface point is seen by at least one sensor footprint during the 24 hour analysis period.

1. Right-click on Simple_Cov's ( ) in the Object Browser.
2. Select Properties ( ).
3. Note the default Definition - Type: is set as Simple Coverage on the Basic - Definition page.
4. Click Cancel .



SIMPLE COVERAGE GRAPHICS

Your 2D Graphics window may display different colors than the image above. The color can be changed in Simple_Cov's ( ) 2D Graphics - Static properties page.

Report Percent Satisfied

Generate a **Percent Satisfied** report. This presents the percentage of the total grid area where the static value of the Figure Of Merit meets the specified satisfaction criterion. In this scenario, the report shows the percentage of the globe that is accessible by any of the three sensors during the analysis period.

1. Right-click on Simple_Cov ( ) in the Object Browser.
2. Select Report & Graph Manager ( ).
3. Select Percent Satisfied report ( ) in the Installed Styles list.
4. Click Generate... .
5. Note the % Satisfied value at the bottom of the report (e.g. 78%).

   78% of the globe is covered by at least one of the three sensors during the analysis time period.

6. Close ( ) the report when finished.
7. Close ( ) the Report & Graph Manager.

Create a Constraint

Once you have defined the grid area, you can specify an object class or a specific object for the points within the grid. You are interested in the percentage of coverage during periods of direct sun.

Create Target Object

Insert a Target ( ) object and define a direct sun lighting constraint. This will be the grid constraint object.

1. Select Target ( ) in the Insert STK Objects tool.
2. Select the Define Properties ( ) method.
3. Click Insert... .
4. Select the Constraints - Sun page.
5. Select Lighting.
6. Ensure Direct Sun is set.
7. Click OK .
8. Rename the Target ( ) Constraint_Template.
9. Clear the check box next to Constraint_Template ( ) in the Object Browser. There is no need to see Constraint_Template ( ) on the 2D or 3D Graphics windows.

Apply the Grid Constraint

Set the Target ( ) object as the grid constraint. It contains the constraint you want to apply to the coverage grid.

1. Right-click on World_Cov' ( ) in the Object Browser.
2. Select Properties ( ).
3. Click **Grid Constraint Options...** on the Basic - Grid page.
4. Ensure Reference Constraint Class is set to Target on the Grid Constraint Options window. For all object classes, the Basic properties of the object, excluding positional information, are applied to the grid points.
5. Select Use Object Instance.
6. Select Constraint_Template.
7. Click **OK** to close the Grid Constraints Options window.
8. Click **OK** to accept the changes and close World_Cov's ( ) properties ( ).

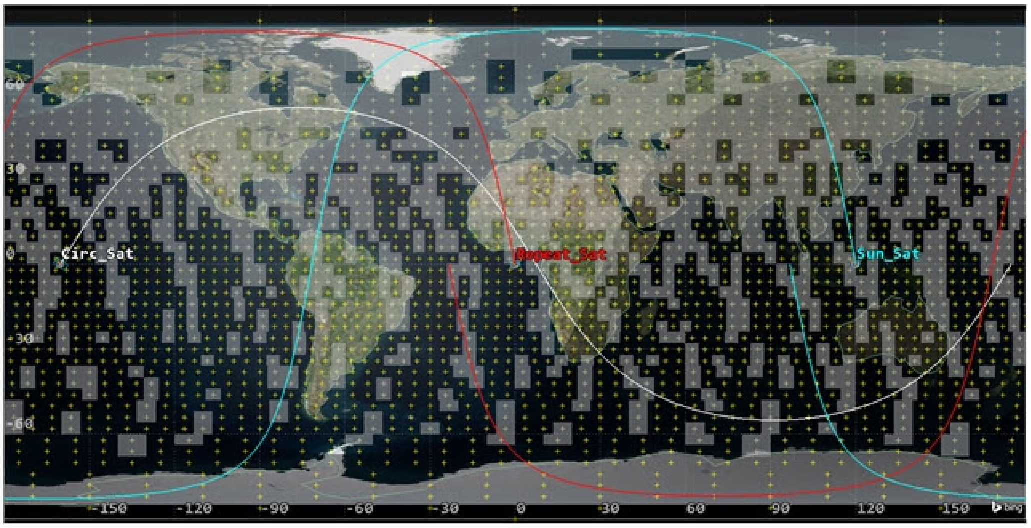
Re-compute Accesses

Since a change was made to the coverage grid, you need to re-compute accesses.

1. Select World_Cov' ( ) in the Object Browser.
2. Extend the CoverageDefinition menu.
3. Select Compute Accesses. There is a progress bar in the lower right corner of STK.
4. Bring the 2D Graphics window to the front when finished.

Determine Coverage Loss

It's obvious from the view in the 2D Graphics window, that you have less coverage using a Direct Sun constraint. Due to the analysis time period, there is more sunlight in the northern hemisphere which you can see on the map. Generate a Percent Satisfied report to determine the percent coverage loss.



SIMPLE COVERAGE WITH DIRECT SUN CONSTRAINT

1. Right-click on Simple_Cov ( ) in the Object Browser.
2. Select Report & Graph Manager ( ).
3. Select Percent Satisfied report ( ) in the Installed Styles list.
4. Click Generate... .
5. Note the % Satisfied value at the bottom of the report (e.g. 45 %).

   Since coverage is now being analyzed during periods of direct sun and not being analyzed during periods of umbra, there's a significant loss of coverage.

6. Close ( ) the report when finished.
7. Close ( ) the Report & Graph Manager.

Measure Number of Accesses

Insert a new Figure of Merit to measure **Number of Accesses**. This will measure the number of independent accesses of points.

1. Clear the check box next to Simple_Cov ( ) in the Object Browser.
2. Select Figure Of Merit ( ) in the Insert STK Objects tool.
3. Select the Define Properties ( ) method.
4. Click **Insert...** .
5. Select World_Cov ( ) in the Select Object window.
6. Click **OK** .
7. Select Number Of Accesses as the Definition - Type on the Basic - Definition page.
8. Keep Compute set to the default Total.
9. Click **OK** .
10. Rename the Figure Of Merit ( ) Num_Access.

Grid Stats Report

Generate a Grid Stats report to see the smallest to largest number of accesses to any point in the grid.

1. Right-click on Num_Access ( ) in the Object Browser.
2. Select Report & Graph Manager ( ).
3. Select Grid Stats report ( ) in the Installed Styles list.

4. Click Generate... .

5. Note the Maximum value (e.g. 8).

   That means at least one point in the grid was accessed on eight different occasions during the analysis period.

6. Note the Minimum value (e.g. 0).

   That means at least one point in the grid was never accessed by any of the three sensors during the analysis period.

7. Close (☒) the report when finished.

8. Close (☒) the Report & Graph Manager.

9. Clear the check box next to World_Cov ( ) in the Object Browser.

Area Target Coverage

You can focus the coverage grid in a confined location using Area Target ( ) objects. For this part of the analysis, you will focus on the continental United States and mainland Canada. Islands and territories will not be taken into consideration.

Insert Area Targets

Insert an Area Target ( ) to model Canada and the continental United States.

1. Select Area Target ( ) in the Insert STK Objects tool.

2. Select the Select Countries and US States ( ) method.

3. Click Insert... .

4. Clear US States on the Select Countries And US States window.

5. Use the Ctrl key to select Canada and United_States_of_America in the countries list on the left. You can insert them individually if desired.
6. Click **Insert** .
7. Click **Close** .

Define a New Coverage Definition

You want to determine coverage time inside the boundaries of the Area Targets (). You will use Repeat_Sens () as the asset. No constraints are necessary.

Insert Coverage Definition

Insert a new Coverage Definition ().

1. Select Coverage Definition () in the Insert STK Objects tool.
2. Select the Define Properties () method.
3. Click **Insert...** .
4. Rename the new Coverage Definition () Country_Cov.

Define Coverage Grid

Define the coverage area of interest to be Canada and the continental United States using the Area Targets ().

1. Select Custom Regions as the Grid Area of Interest - Type on the Basic - Grid page.
2. Click **Select Regions...** .

3. Use the Ctrl key to select Canda and United_States_of_America in the Area Targets list on the left.

4. Click Move ( ) to move the Area Targets to the Selected Regions list on the right.

5. Click OK to close the Select Regions window.

6. Set the Point Granularity - Lat/Lon to 1 deg.

7. Click Apply .

8. Bring the 2D Graphics window to the front.

9. Zoom In ( ) so that you only see Canada and United States.

COVERAGE GRID CONFINED TO AREA TARGETS

Your 2D Graphics window may display different colors than the image above. The grid point colors can be changed by changing Country_Cov's ( ) color in the Object Browser or on Country_Cov's ( ) 2D Graphics - Attribute properties page.

10. If desired, you can Zoom In ( ) and center the 3D Graphics window to the same view as the 2D Graphics window.

Assign Coverage Asset

Define Repeat_Sens ( ) as the Coverage Asset.

1. Return to Country_Cov's ( ) properties ( ).
2. Select the Basic - Assets page.
3. Select Repeat_Sens ( ) in the Assets list.
4. Click **Assign** .
5. Click **Apply** .

Turn Off Grid Display

You will display Figure Of Merit graphics, so turn off the grid point display.

1. Select the 2D Graphics - Attributes page.
2. Clear Show Points in the Show - Grid field. This turns off the visual grid inside the Area Target ( ) objects. Analytically, they're still there.
3. Click **OK** .

Compute Accesses

You can compute accesses from the Object Browser vice the CoverageDefinition menu.

1. Right-click on Country_Cov ( ) in the Object Browser.
2. Select CoverageDefinition.
3. Select Compute Accesses. There is a progress bar in the lower right corner of STK.

Figure Of Merit

User a Figure Of Merit ( ) to determine the amount of time during which the grid points are covered by Repeat_ Sens ( ).

Insert Figure of Merit

Insert a Figure Of Merit ( ) to measure the quality of coverage of Country_Time ( ).

1. Select Figure Of Merit ( ) in the Insert STK Objects tool.
2. Select the Define Properties ( ) method.
3. Click **Insert...** .
4. Select Country_Cov ( ) in the Select Object window.
5. Click **OK** .
6. Rename the Figure Of Merit ( ) Cov_Time.

Measure Coverage Time

Set the Figure Of Merit to **Coverage Time**. It will measure the amount of time during which grid points are covered.

1. Set the Definition - Type to Coverage Time on the Basic - Definition page.
2. Change Compute: to Total Time Above.

   Total Time Above computes the amount of time (over the entire coverage interval) during which a point is covered by at least the specified number of assets based on the entire coverage interval.

3. Click Apply .

Generate a Grid Stats Report

Generate a report to determine the minimum and maximum amount of time any of the grid points are covered by Repeat_Sens ( ).

1. Right-click on Cov_Time ( ) in the Object Browser.
2. Select Report & Graph Manager ( ).
3. Select Grid Stats report ( ) in the Installed Styles list.
4. Click Generate... .
5. Note the Maximum time (e.g. 49 seconds).

   That means at least one point in the grid was accessed for a total of 49 seconds during the analysis period.
6. Return to Cov_Time's ( ) properties ( ).

Defining Static Graphics for the Figure Of Merit

Define static graphics for the Figure Of Merit on the 2D Graphics - Static page.

1. Select the 2D Graphics - Static page.
2. Set Filled Area - % Translucency to 30 in the Show Points As field.
3. Select Show Contours in the Display Metric field.
4. Click Remove All in the Level Attributes field.

5. Set the following in the Level Adding field:

Option	Value
Start:	0 sec
Stop:	round down to the nearest integer from the Maximum (sec) value in the Grid Stats report (e.g. 49 sec)
Step:	5 sec

6. Click Add Levels .
7. Change the Color Ramp Start Color: to red in the Level Attributes field.
8. Change the End Color: to blue in the Level Attributes field.

   Points with no coverage will be red and any points at or above your highest Level Attribute value will be blue.
9. Select Natural Neighbor in the Contour Interpolation (points must be filled) field. Color is applied smoothly over all points in the grid to differentiate contour levels.
10. Click Apply

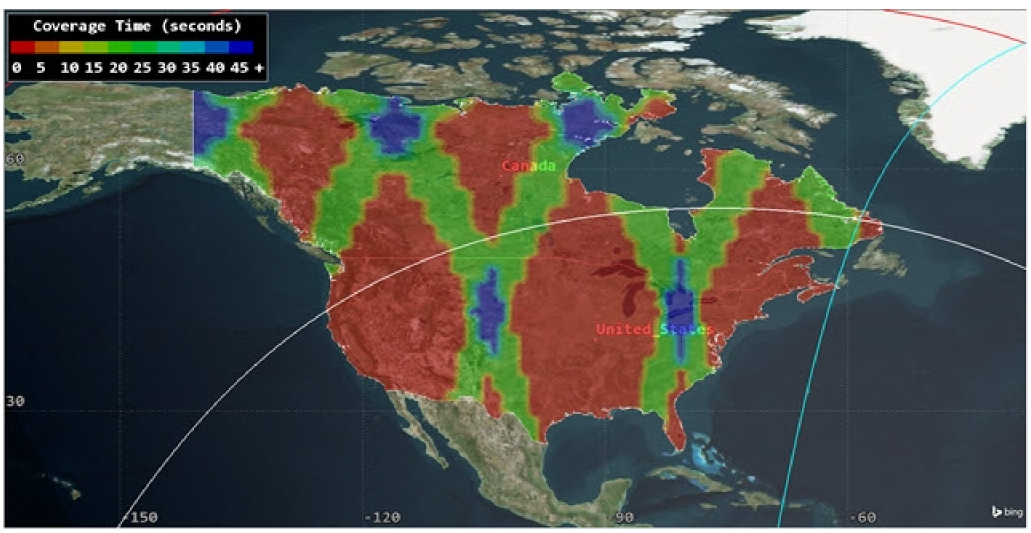
Set 2D and 3D Graphics Windows Legends

Once you have set the contours for coverage, you can set the display of the contour key, or **legend**.

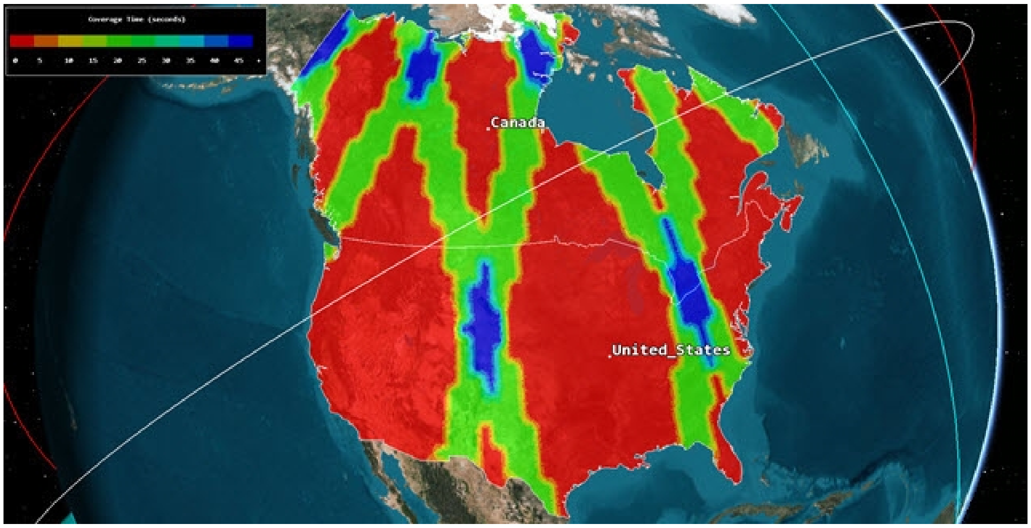
1. Return to Cov_Time's ( ) properties ( ) 2D Graphics - Static page.
2. Click Legend... .
3. Click OK to close Cov_Time's ( ) properties ( ).
4. Click Layout... in the Static Legend for Cov_Time window.
5. Set the following on the Figure of Merit Legend Layout window:

Option	Value
2D Graphics Window - Show at Pixel Location	on
3D Graphics Window - Show at Pixel Location	on
Text Options - Title:	Coverage Time (seconds)
Text Options - Number Of Decimal Digits:	0
Range Color Options - Color Square Width (pixels):	50

6. Click OK .
7. Close () the Static Legend for Cov_Time window.
8. Bring the 2D and 3D Graphics windows to the front.
9. Note Snap Frame () in both the 2D and 3D Graphics windows. You could use Snap Frame () to take a picture of the map to place in a PowerPoint slide or in a document.



2D GRAPHICS WINDOW WITH COVERAGE CONTOURS



3D GRAPHICS WINDOW WITH COVERAGE CONTOURS

Save Your Work

1. Close any open reports, properties and the Report & Graph Manager.
2. Save ( ) your work.

Summary

You placed three Satellite ( ) objects into the scenario using circular, repeating ground trace and sun synchronous orbits. All three satellites had similar Sensor ( ) objects. You built a Coverage Definition ( ) object and set the grid definition to global. Using all three Sensor ( ) objects, you computed access. Using a Figure Of Merit ( ) object, you learned about Simple Coverage and how to analyze the percentage of the Earth accessed during a twenty four hour period. Next, you loaded a Target ( ) object at the Prime Meridian (default location), and set a direct sun constraint. Returning to the Coverage Definition ( ) object, you applied the constraint across the coverage grid and recalculated coverage to see how the direct sun constraint affected the percentage of coverage. The next step was to add a second Figure Of Merit ( ) object and determine the number of accesses against each point in the coverage grid. Switching gears, you loaded two Area Target ( ) objects which outlined the continental United States and Canada. With a new Coverage Definition ( ) object, you focused coverage inside of the Area Target ( ) objects using only the Sensor ( ) object attached to the satellite in the repeating ground trace orbit. This time, you configured a new Figure Of Merit ( ) object to focus on how long each point in the coverage grid was covered by the Sensor ( ) object. Finally, you learned how to apply static contours to both the 2D and 3D Graphics windows.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information of various subjects. Now's a good time to go back through this tutorial and view that information.

The following tutorials are recommended for further training:

- **Using STK Coverage**: Teaches you animation contours.
- **Attitude Coverage**: STK Attitude Coverage combines features of STK Attitude and STK Coverage capabilities to enable you to analyze coverage in various directions over time, using several attitude-dependent figures of merit.
- **Getting started with STK Coverage**: More focus on setting up contours and how to analyze multiple sensors passing over a single point.
- **Modeling GPS Position Accuracy using STK Coverage**: Covers navigation accuracy over the continental United States and how to calculate coverage against a single object.
- **Position Accuracy in Mountainous Terrain**: Requires STK 12 or newer. Focuses on navigation accuracy in mountainous terrain and how terrain affects your coverage.

Part 9: Introduction to the AzEl Mask Tool and Volumetrics

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro
- Analysis Workbench
- Coverage

Problem

Engineers and operators require a quick way to determine if the Earth, local terrain, nature and man-made structures affect visibility between ground sites and satellites for a variety of purposes such as communications, imaging, radar and general situational awareness. A country's space program is planning to install a satellite tracking radar in an area that has distant hills and a large mountain range. A communication antenna enclosed by a large radome will be constructed close by. Engineers want to determine how much impact the Earth, terrain and the radome will have on the radar's field of view.

Solution

Using STK, insert Facility objects which will simulate the radar and communication sites. Use a local terrain file for analysis and determine access times between the radar field of view and five earth observation satellites. Use the AzEl Mask Tool to determine if the communication site's radome further degrades the radar's access times to the satellites. Insert an Area Target object to outline the approximate maximum distance that a satellite can be observed by the radar site. Apply the Analysis Workbench's Spatial Analysis Tool to build a constrained grid to determine how much of the radar's field of view is blocked by the Earth, terrain and the radome at a selected distance and altitudes.

What you will learn

Upon completion of this tutorial, you will understand the following:

- The AzEl Mask Tool
- The Analysis Workbench Spatial Analysis Tool
- The Analysis Workbench Time Tool
- The Volumetric object

Creating a new scenario

Create a new scenario.

1. Launch STK ( ).
2. Click **Create a Scenario** in the Welcome to STK window.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value
Name:	AzElMask_Volumetrics
Location:	Default
Start:	1 Aug 2022 12:00:00.000 UTCG
Stop:	2 Aug 2022 12:00:00.000 UTCG

4. Click OK when you finish.
5. Click Save () when the scenario loads. A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location.
7. Click Save .

Note: Save () often!

Turning off terrain server

A local analytical terrain file will be used in this analysis. Disable the Terrain Server.

1. Right click on AzElMask_Volumetrics's () in the Object Browser.
2. Select Properties ().
3. Select the Basic - Terrain page.
4. Clear the Use terrain server for analysis check box.
5. Click OK to accept the change and close the Properties Browser.

Adding analytical and visual terrain

An STK Terrain File (pdtt) located in the STK install area will be used for analysis and situational awareness in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.
2. Click Globe Manager () in the 3D Graphic window toolbar.
3. Extend the Add Terrain/Imagery () menu on the Globe Manager toolbar.
4. Select Add Terrain/Imagery () in the shortcut menu.
5. Click the Path: ellipsis () in the Globe Manager: Open Terrain and Imagery Data dialog box.
6. Navigate to <STK Install Folder>\Data\Resources\stktraining\imagery (e.g. This PC then C:\Program Files\AGI\STK 12\Data\Resources\stktraining\imagery) in the Browse For Folder dialog box.
7. Click **OK** .
8. Select RaistingStation.pdtt.
9. Click **Add** .
10. Click **Yes** to enable terrain for analysis in the Use Terrain for Analysis prompt.

Decluttering 3D Graphics window labels

Label Declutter is used to separate the labels on objects that are in close proximity for better identification in small areas.

1. Bring the 3D Graphics window to the front.
2. Click Properties () in the 3D Windows toolbar.

3. Select the Details page.

4. Select Enable in the Label Declutter frame.

5. Click OK .

Inserting the radar site

Use a Facility object as the radar site location.

1. Bring the Insert STK Objects Tool () to the front.

2. Select Facility () in the Select An Object To Be Inserted: list.

3. Select Insert Default () in the Select A Method: list.

4. Click Insert...

5. Right click on the Facility1 () in the Object Browser.

6. Select Rename in the shortcut menu.

7. Rename the Facility1 () to Radar_Site.

8. Open Radar_Site's () properties ().

Moving the radar site to its location

The radar site is located in Germany.

1. Select the Basic - Position page.

2. Set the following:

Option	Value
Latitude:	47.8996 deg
Longitude:	11.1142 deg

3. Click Apply .

Defining an Azimuth-Elevation Mask

Define an Azimuth -Elevation Mask (AzEl Mask) to use local terrain analytically. The AzEl Mask constraint leverages a provided or computed AzEl Mask to determine visibility.

1. Select the Basic - AzElMask page.
2. Set the following:

Option	Value
Use:	Terrain Data
Use Mask for Access Constraint	on

3. Click OK .

Using a Sensor Object to Define the Radar's Field of View

Use a Sensor object to simulate the radar system's field of view (FOV).

1. Insert a Sensor ( ) object using the Insert Default ( ) method.
2. Select Radar_Site ( ) in the Select Object dialog box.

3. Click OK .

4. Rename the Sensor1 ( ) to Radar_FOV.

Creating the radar field of view

Use a Complex Conic sensor pattern. Complex Conic sensor patterns are defined by the inner and outer half angles and minimum and maximum clock angles of the sensor's cone.

1. Open Radar_FOV's ( ) properties ( ).

2. Select the Basic - Definition page.

3. Open the Sensor Type: shortcut menu.

4. Select Complex Conic.

5. Set the Complex Conic - Half Angles - Outer: value to 180 deg.

6. Click Apply .

By setting the Half Angles - Outer: value to 180 deg (vertical angle) and leaving the default Clock Angles values (horizontal angle), you've created a 360 degree FOV.

Raising the antenna's field of view

The radar's antenna is positioned twenty (20) feet above the ground's surface. Sensor Location properties enable you to position a sensor with respect to its parent object. A Facility object's positive (+) Z body points to the center of the earth. If you want to move the Sensor object up, you have to use a negative (-) Z value.

1. Select the Basic - Location page.

2. Open the Location Type: shortcut menu.

3. Select Fixed.

4. Set the Fixed Lcoation - Z: field to -20 ft.
5. Click **Apply** .

Using the AzEl mask constraint

A Sensor object can use its parent object's AzEl Mask.

1. Select the Constraints - Basic page.
2. Select Az-El Mask.
3. Click **Apply** .

Visualizing the terrain constraint

2D Projection Graphics for sensors control the display of sensor projection graphics in the 2D and 3D Graphics windows. In order to visualize the constraints that the Sensor object is using, you have to define which constraints can be used to modify the field of view of the sensor.

1. Select the 2D Graphics - Projection page.
2. Select Use Constraints in the Field of View frame.
3. Select AzElMask in the list.
4. Click **Apply** .

3D Graphics Projection Properties

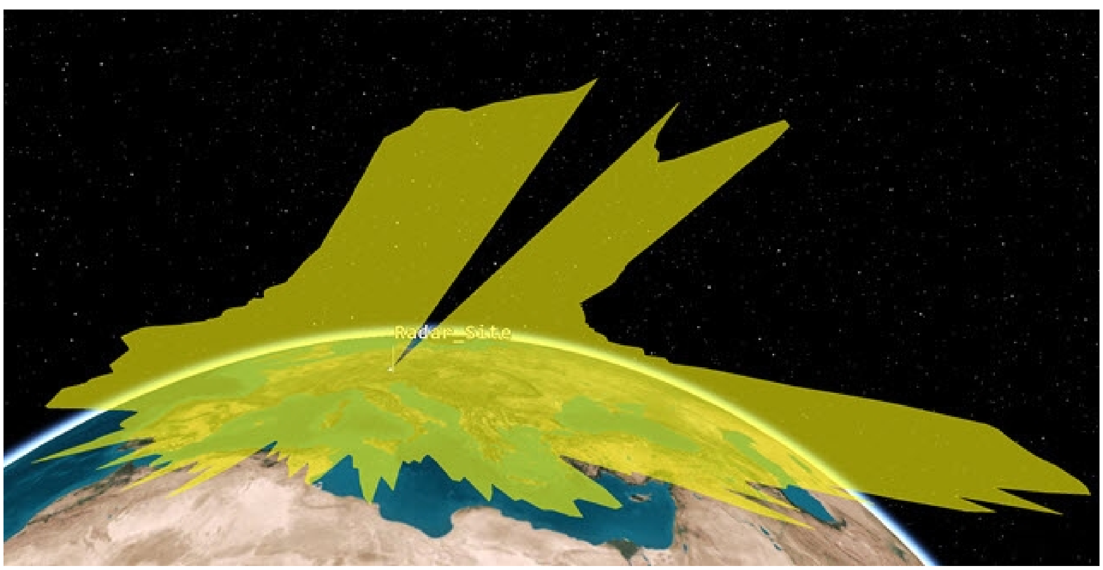
3D Graphics Properties for Sensors - Projection is used to control the display of a sensor's cone into space as well as the sensor's extension into space. Extension distances define the length of a sensor's projection. For a constant space projection, enter the projection length in the Space Projection field. In this case, the distance is computed so that the projection of the outermost point on the contour along the bore sight is equal to the distance entered. This is a visualization property, not an analytical property.

1. Select the 3D Graphics - Projection page.
2. Set the Extension Distances - Space Projection: field 50 km.
3. Click OK .

Viewing the radar antenna's field of view

You are using a Sensor object to visualize the projected field of view of a radar antenna.

1. Bring the 3D Graphics window to the front.
2. Click Home View ( ) in the 3D Graphics toolbar.
3. Change you view so that you can see Radar_FOV's ( ) field of view.



SENSOR FIELD OF VIEW

Your image might look different from the image in this tutorial. You can orient the 3D Graphics window to obtain the same view but it's not required.

If you were only using the Line of Sight constraint, the sensor field of view would be round. In this instance, you are taking into account the central body (Earth) and terrain which is causing the blockage of the sensor's field of view.

Inserting Earth Observation Satellites

The radar site's primary purpose is to track five (5) Earth observation satellites.

1. Insert a Satellite ( ) object using the From Standard Object Database ( ) method.
2. Set the following in the Standard Object Database tool:

Option	Value
Owner:	Germany
Mission:	Earth Observation

3. Click **Search** .
4. Press **Ctrl** on your keyboard and select TanDEM-X and TerraSAR-X in the Results: list.
5. Click **Insert** .
6. Click **Close** to exit the Standard Object Database tool after both satellites are propagated.

Removing unneeded objects

For your scenario, you won't be using the Sensor objects attached to your satellites.

1. Select all the Sensor ( ) objects attached to TanDemX_36605 ( ) in the Object Browser.
2. Click Delete ( ) in the Object Browser toolbar.
3. Click **Delete** in the Delete Objects dialog box.

4. Select all the Sensor ( ) objects attached to TerraSarX_31698 ( ) in the Object Browser.
5. Click Delete ( ) in the Object Browser toolbar.
6. Click Delete in the Delete Objects dialog box.

Determining Access

Determine the total time each satellite appears within the sensor's field of view. That is considered access time. You will use this value as a benchmark to see if the radome affects accesses to the satellites.

1. Right click on Radar_FOV ( ) in the Object Browser.
2. Select Access ( ).
3. Select both Satellite ( ) objects in the Access Tool's Associated Objects list.
4. Click Compute .
5. Click Access... in the Reports frame.
6. Scroll to the bottom of the report.
7. Note the Total Duration value in the Global Statistics section (e.g. ~ 6429 seconds).

Saving access report as an external text file

Save the access report outside of STK. This is a safe way to retain the original analysis values.

1. Return to the access report.
2. Click Save as text ( ) in the Access report toolbar.
3. Ensure your scenario folder displays in the in Address bar in the Save Report dialog box.

4. Enter Sensor to Satellites Terrain Only in the File name: field.
5. Click **Save** .
6. Close the access report.
7. Close the Access Tool.

Inserting Communication Site Radome

Construction crews will build a large communication site radome less than one half a kilometer from the proposed radar site. Use a Facility object as the radar site location.

> **Note:** In this scenario, you're using a Facility object to simulate the communication site's radome. If you were actually performing this analysis against an actual building, you would need to consider creating your own 3D model built to specifications.

1. Insert a Facility ( ) object using the Insert Default ( ) method.
2. Rename Facility2 ( ) to Comm_Radome.
3. Open Comm_Radome's ( ) properties ( ).
4. Select the Basic - Position page.
5. Set the following:

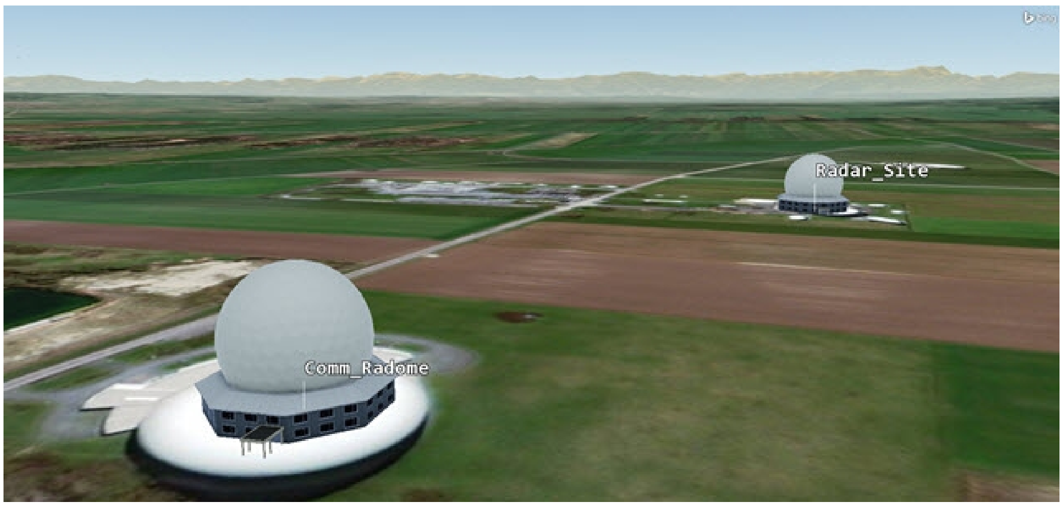
Option	Value
Latitude:	47.9020 deg
Longitude:	11.1135 deg

6. Click **OK** .

Viewing the Communication Radome

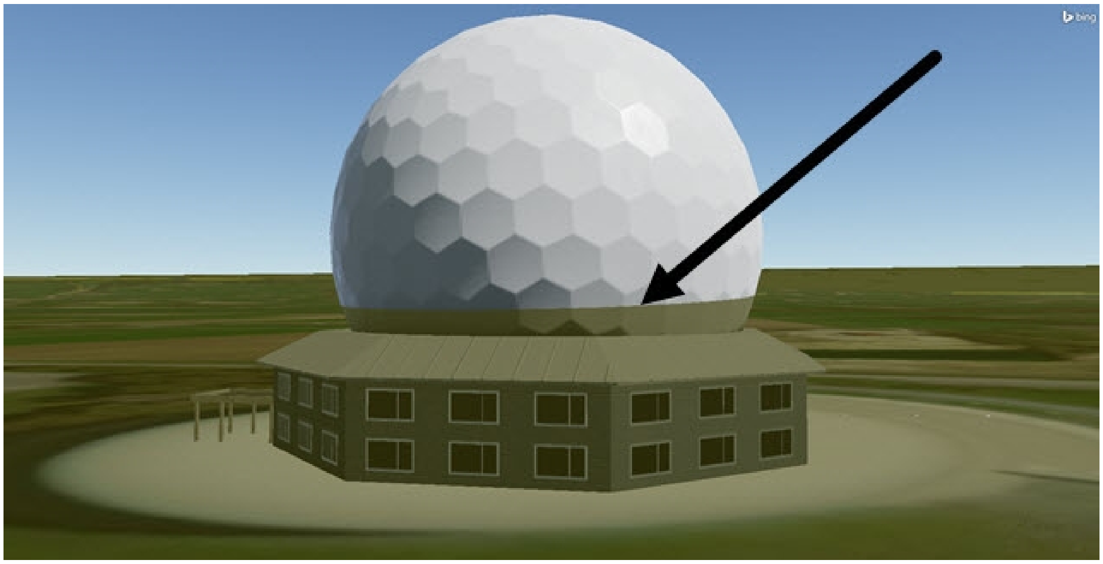
View the radome in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.
2. Right click on Comm_Radome ( ) in the Object Browser.
3. Select Zoom To.
4. Change your view so that you can see the communication site radome and the and radar site.



RADAR SITE, COMMUNICATIONS RADOME AND MOUNTAINS

5. Use your mouse to set the view so that you can see how Radar_FOV's ( ) projection cuts through Comm_Radome's ( ) 3D Model.



SENSOR FIELD OF VIEW PASSING THROUGH 3D GRAPHICS MODEL

If you look closely, you can see that the sensor's projection cuts through the communication site's radome. The Facility object's 3D Graphics model is not being used as an obstruction during analysis. In order to use the Facility object's 3D graphics model as an obstruction, you use the AzEl Mask tool.

Opening the AzEl Mask Tool

Use the AzEl Mask tool to create a body masking file (.bmsk) that can be used in access computations and visualization. The static body masking files (.bmsk) that are created are used to restrict visibility to a sensor.

1. Maximize your 3D Graphics window.
2. Select Radar_FOV () in the Object Browser.
3. Open the Sensor menu item at the top of STK.
4. Select AzEl Mask.

The Az/El Mask View window allows you to see the obscuring objects in the six views used in generating the contours. The views will be shown in successive fashion when the Compute button is clicked.

The AzEl Mask window enables you to identify obscuring objects and define the instant in time at which obscuration contours are computed.

Preparing the AzEl Mask Tool

Start by setting up the AzEl Mask Tool prior to creating a .bmsk file. Set Comm_Radome ( ) as the obsurring object and the window dimension to 700.

1. Move the AzEl Mask window (AzElMask for Radar_FOV) to the right so that it isn't on top of the Az/El Mask View window.
2. Select Comm_Radome ( ) in the AzEl Mask window's Obscuring Objects list.
3. Set the Window Dim: value to 700 in the Data frame.
4. Click **Apply** .

 > **Note:** Larger window sizes produce more accurate masks which require more access computation time. A mask file cannot be generated if the window dimensions are too small or larger than the STK workspace. If the Dim: value of 700 places this window outside of your STK workspace, decrease the value until it's inside the STK workspace.

5. Click **Compute...**
6. Ensure your .bmsk file (use the default file name) is being saved in your scenario folder in the Select Body Mask File dialog box.
7. Click **Save** .
8. Close the AzEl Mask window and the Az/El Mask View window when the computation is complete.

Constraining the sensor with the AzEl Mask

You can use the body mask file (.bmsk) as a Sensor object's access constraint.

1. Open Radar_FOV's ( ) properties ( ).
2. Select the Basic - Sensor AzEl Mask page.
3. Open the Use: shortcut menu.
4. Select MaskFile.
5. Click the Mask File: ellipsis ( ).
6. Browse to your scenario folder if required when the Select File dialog box opens.
7. Select Radar_FOV.bmsk in the list.
8. Click **Open** .
9. Select Use Mask for Access Constraint.
10. Click **Apply** .

Visualizing the sensor AzEl Mask constraint

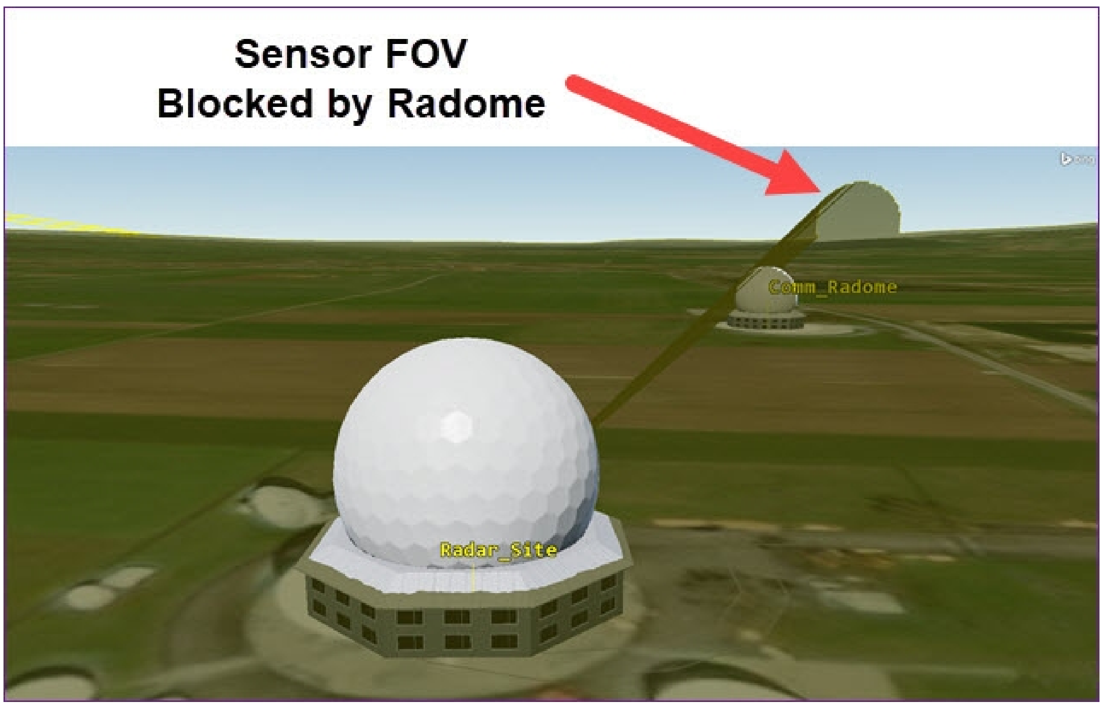
In order to visualize the Sensor AzEl Mask constraint, follow the same procedure as you did to visualize the terrain Az-El Mask.

1. Select the 2D Graphics - Projection page.
2. Leave AzElMask selected in the Field of View - Use Constraints frame.
3. Scroll down the Field of View - Use Constraints list until you locate SensorAzElMask.
4. Press **Ctrl** on your keyboard and select SensorAzElMask.
5. Click **OK** .

Viewing the sensor AzEl Mask constraint in the D Graphics window

You can view the constraint in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.
2. Zoom To Radar_Site ().
3. Change your view so that you can see Radar_Site (), Comm_Radome (), and Radar_FOV's () field of view being affected by Comm_Radome ().



SENSOR BLOCKED BY THE RADOME

Determining Access

Determine the total time each satellite appears within the sensor's field of view.

1. Right click on Radar_FOV ( ) in the Object Browser.
2. Select Access... ( ).
3. Select both Satellite ( ) objects in the Access Tool's Associated Objects list.
4. Click Access... in the Reports frame.
5. Scroll to the bottom of the report.
6. Note the Total Duration value in the Global Statistics section (e.g. ~ 6232 seconds).

Comparing data

Compare access data between the access using terrain and the access using terrain and a .bmsk file. The best result would be that you don't lose any access duration.

1. Open Windows File Explorer ( ).
2. Browse to your scenario folder (e.g. C:\Users\username\Documents\STK 12\AzElMask_Volumetrics).
3. Open the Sensor to Satellites Terrain Only.txt file.
4. Return to STK.
5. Compare the Global Statistics Total Duration time in the text file to the Total Duration time in the Access Report.
   - Did the communication site radome affect your total duration access time?
6. Close both reports and the Access Tool when finished.
7. Open the Analysis menu.
8. Select Remove All Accesses.

Analyzing the radar field of view

Based on the curvature of the Earth and that both satellites being tracked by the radar are in a low Earth orbit (LEO), you want to determine how much of the radar's field of view is blocked by the Earth, terrain and the radome in a 360 degree circle using a radius of 3000 kilometers from the radar site. A 3D volume of space will be analyzed inside the sphere between 10 to 700 kilometers in altitude. In order to determine how much the radar field of view is affected, you will use an Area Target object, a Volumetric object, and the Analysis Workbench Spatial Analysis Tool.

Inserting an Area Target

Insert an Area Target ( ) to model the 300 km circle on the ground.

1. Insert an Area Target ( ) object using the Area Target Wizard ( ) method.
2. Set the following in the Area Target Wizard ( ):

Option	Value
Name:	OpsArea
Area Type:	Ellipse
Semi-Major Axis:	3000 km
Semi-Minor Axis:	3000 km
Centroid:	47.8996 deg (Latitude)
Centroid:	11.1142 deg (Longitude)

3. Click OK .

Viewing the Area Target Object in the 3D Graphics window

View the Area Target in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.
2. Click Home View ( ).
3. Move your view so that you can see OpsArea ( ).

3D GRAPHICS WINDOW VIEW OF THE AREA TARGET

Opening the Analysis Workbench Time Tool

There is no need to calculate the radar field of view for the entire analysis period of 24 hours. You can use the Analysis Workbench Time tool to create a one (1) second interval. You will use this interval when analyzing the radar's field of view.

1. Right click on AzElMask_Volumetrics ( ) in the Object Browser.
2. Select Analysis Workbench ( ) in the shortcut menu.

3. Select the Time tab when the Analysis Workbench opens.

4. Ensure AzElMask_Volumetrics () is selected in the object list on the left.

Creating a Fixed Time Interval

You want a time interval of one (1) second.

1. Click Create New Interval ( ) which is an icon located between the object list on the left and the components list on the right.

2. Set the following in the Add Time Component dialog box:

Option	Value
Type:	Fixed Interval
Name:	One_Second
Stop Time:	1 Aug 2022 12:00:01.000 UTCG

3. Click OK to close the Add Time Component dialog box.

Creating the Spatial Analysis Reference Grid Component

The Anslysis Workbench's **Spatial Analysis tool** enables you to create calculations and conditions that depend on locations in 3D space which are, in turn, provided by user-definable volume grids. You need to create two (2) grids: a Cartographic grid and a Constrained grid. The reference grid will be used to create a 3D volume of space encompassing the Area Target object's sphere between 10 to 700 kilometers in altitude.

1. Select the Spatial Analysis tab at the top of the Analysis Workbench Tools interface.

2. Select OpsArea () in the object list.

3. Click Create New Volume Grid ().

4. Ensure the Type: is Cartographic in the Add Spatial Analysis Component dialog box.

5. Change the Name: to Ref_Grid.

> **Note:** By default, Automatically fit to Area Target is enabled and attaches the center of the grid to the Area Target's centroid. Constrain active grid points within Area Target is also enabled and tells STK to analyze the grid points contained inside the Area Target, not the overflow points outside the Area Target.

6. Click **Set Grid Values...**

7. Set the following in the Altitude frame when the Grid Values dialog box opens:

Option	Value
Minimum:	10 km
Maximum:	700 km
Number of Steps:	20

The number of steps determines how many grid points are added to the volume for computation and analysis.

8. Click **OK** to close the Grid Values dialog box.

9. Click **OK** to close the Add Spatial Analysis Component dialog box.

Creating the Spatial Analysis Constrained Grid Component

A constrained volume grid is one in which the grid points from the reference grid are available only when the spatial condition is satisfied.

1. Ensure OpsArea ( ) is selected in the object list in the Spatial Analysis tool.
2. Click Create New Volume Grid ( ).
3. Set the following in the Add Spatial Analysis Component dialog box:

Option	Value
Type:	Constrained
Name:	OpsArea_Constrained

Selecting the Reference Grid

Select the Ref-Grid ( ) created previously as the Reference Grid.

1. Click the Reference Grid: ellipsis ( ).
2. Select OpsArea ( ) in the object list when the Select Reference Volume Grid dialog box opens.
3. Select Ref_Grid ( ) in the Volume Grids for: OpsArea list.
4. Click OK to close the Select Reference Volume Grid dialog box.

Setting the Spatial Condition

Select the Radar_FOV's ( ) Visibility as the Spatial Condition.

1. Click the Spatial Condition: ellipsis ( ).
2. Select Radar_FOV ( ) in the object list when the Select Reference Spatial Condition dialog box opens.

3. Select Visibility ( ) in the Spatial Conditions for: Radar_FOV list. This will apply the constrained visibility of Radar_FOV () to the 3D volume grid.
4. Click OK to close the Select Reference Spatial Condition dialog box.
5. Click OK to close the Add Spatial Analysis Component dialog box.
6. Click Close to close the Analysis Workbench.

Inserting Volumetrics Object

The Volumetric object defines a 3-dimensional grid of points using various coordinate definitions, with respect to various reference coordinate systems from the Vector Geometry tool. It also defines the conditions and calculations that depend on locations in 3D space and evaluates these conditions and calculations across grid points.

1. Insert a Volumetric () object using the Insert Default () method.
2. Click Save ().

Defining the Volume grid

The default volume grid encircles the Earth up to an altitude of 1000 kilometers. Change it to the constrained grid.

1. Open the Volumetric1's () properties ().
2. Select the Basic - Definition page.
3. Click the Volume Grid: ellipsis ().
4. Select OpsArea () in the object list when the Select Volume Grid for Volumetric1 dialog box opens.

5. Select OpsArea_Constrained ( ) in the Volume Grids for: OpsArea list.
6. Click OK to close the Select Volume Grid for Volumetric1 dialog box.
7. Click Apply .

Selecting the Spatial Calculation

A Spatial Calculation is a scalar calculation that depends on both time and location.

1. Select the Spatial Calculation: check box.
2. Click the Spatial Calculation: ellipsis ().
3. Select OpsArea () in the object list when the Select Spatial Calculation for Volumetric1 dialog box opens.
4. Select Altitude ( ) in the Spatial Calculations for: OpsArea list.
5. Click OK to close the Select Spatial Calculation for Volumetric1 dialog box.
6. Click Apply .

Volumetric Basic Interval

Apply the one second time interval created in the Analysis Workbench Time Tool.

1. Select the Basic - Interval page.
2. Click the Analysis Interval: ellipsis ().
3. Select AzElMask_Volumetrics () in the object list when the Select Interval or List dialog box opens.
4. Select One_Second ( ) in the Components for: AzElMask_Volumetrics list.

5. Click **OK** to close the Select Interval or List dialog box.

6. Click **Apply** .

7. Save ( ) the scenario.

Computing Visibility Inside the Grid

The best case scenario would have 100 percent visibility inside the grid. However, the curvature of the Earth, terrain, and the radome will reduce this percentage.

1. Select Volumetric1 ( ) in the Object Browser.

2. Open the Volumetric shortcut menu.

3. Select Compute.

Generating a report

Generate a report that shows how much of the radar's field of view is visible.

1. Right click on Volumetric1 ( ) in the Object Browser.

2. Select Report & Graph Manager... ( ).

3. Select the Satisfaction Volume ( ) report in the Installed Styles list when the Report & Graph Manager opens.

4. Click **Generate...** .

   You can see in the report that the radar field of view's percent satisfied is approximately 45 percent. Remember, you computed this starting at a low altitude of only 10 kilometers. There will be more losses at lower altitudes due to the central body (Earth), terrain and the radome.

5. Close the Satisfaction Volume report and the Report & Graph Manager when finished.

Displaying Visibility Inside the Grid

The Volumetric 3D Graphics Grid page is used to define the 3D Graphics Volumetric grid properties for the Volumetric Definition.

1. Return to Volumetric1's ( ) properties.
2. Select the 3D Graphics - Grid page.
3. Clear Show Grid. This will make the grid look better for a briefing or presentation. If you were analyzing something like Bit Error Rates per grid point you might leave this on. By clicking on a point in the 3D Graphics window, you will receive a value for that point. In this scenario, they are on or off.
4. Click **Apply** .

Viewing Volumetric 3D Graphics Volume

The Volumetric 3D Graphics Volume page is used to show active grid points or spatial calculation levels. Focus on spatial calculation levels. These levels represent straight line distances from the parent object.

1. Select the 3D Graphics - Volume page.
2. Select the Spatial Calculation Levels radio button.
3. Click **Insert Evenly Spaced Values...** at the bottom of the page.
4. Set the following in the Insert Evenly Spaced Values dialog box:

Option	Value

Units	km
Start Value:	10 (km)
Stop Value:	700 (km)
Step Size:	100 (km)

5. Click **Create Values** .

Adjusting translucency

You can adjust translucency of the colors in order to make the levels stick out or fade depending on your desired view. In this case, you want to be able to see the lower altitude colors more than the higher altitude colors. The Earth, terrain, and radome affect the lower altitude colors more than the higher altitude colors. You can use the Translucency slider or manually type in the percentage. In this case, type them in.

1. Set the following in the % column which is located in the Fill Levels list.

Value km	%
10	10
110	20
210	40
310	40
410	50
510	50
610	60
700	60

2. Click **Apply** .

Displaying Volumetric 3D Graphics Legends

The Volumetric 3D Graphics Legends page allows you to place a legend in the 3D Graphics window which explains what the colors mean.

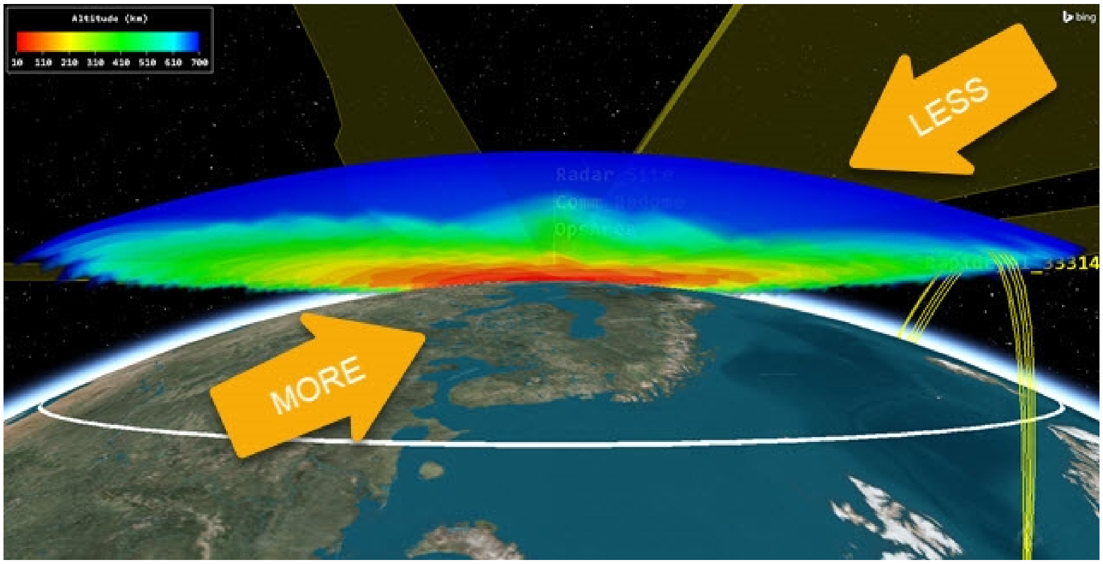
1. Select the 3D Graphics - Legends page.
2. Select the Fill Legend tab.
3. Set the following:

Option	Value
Show Legend	on
Title:	Altitude (km)
Number Of Decimal Digits:	0
Color Square Width (pixels):	40

4. Click OK .

Viewing the contours

1. Bring the 3D Graphics window to the front.
2. Use your mouse to change your view and get an idea of how obscurations affect the different levels of altitude.



RADAR FIELD OF VIEW OBSCURATION

Summary

A new radar site is being proposed that will track LEO satellites. You loaded analytical terrain into your scehario that covers the area in which the radar site is going to be built. You then used a Sensor object to create the field of view of the radar. You propagated two satellites and generated an access between the sensor and the satellites to create a benchmark access time. Next, you placed a Facility object where a new communications radome will be constructed. You used the AzEl Mask tool to determine if the radome affects the sensor's field of view. Generating another access report, you determined that the radome will affect your overall access time to the satellites. Next, you used the Analysis Workbench Time tool to create a one second interval to be used with a Volumetric object's compute time. Then, using the Analysis Workbench Spatial Analysis tool, you created a reference grid inside of an Area Target object and a constrained grid which then applied the Sensor object's constraints to the 3D volume of space. You determined that a significant amount of your volume is obscured by the Earth, terrain and the radome.

On your own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information of various tools and functions. Now's a good time to go back through this tutorial and view that information. You can add other models to your scenario and determine their obscuration affects. You can adjust the altitude of your reference grid and recalculate volume obscuration. Have fun!

Part 10: Perform Trade Studies with Analyzer

Required Product Licenses: STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Important: Additional installation - *Analyzer*. You can obtain the necessary install by visiting **http://support.agi.com/downloads** or calling AGI support.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- Coverage
- STK Analyzer

Problem

Engineers and operators require a quick way to determine how various orbital parameters such as semi-major axis, eccentricity, inclination, argument of perigee, right ascension of the ascending node or true anomaly will effect the ability of a sensor or camera to view the surface of the Earth. In this lesson, you want to quickly run multiple trade studies to determine how inclination, eccentricity or a combination of both will effect the percentage of coverage over the entire Earth during a 24 hour period.

Solution

Use STK Pro and STK's *Coverage* and *Analyzer* capabilities to run Parametric and Carpet Plot analyses. The studies will determine the best combination of inclination and eccentricity that provides the highest percentage of global coverage.

What You Will Learn

Upon completion of this tutorial, you will understand:

- *Analyzer*
- *Analyzer* parametric studies
- *Analyzer* carpet plots

Video Guidance

Create a New Scenario

Create a new scenario.

1. Launch STK ().
2. In the Welcome to STK window, click Create a Scenario ().
3. Enter the following in the New Scenario Wizard:

Option	Value
Name:	STK_Analyzer
Location:	Default
Start:	1 Jul 2020 16:00:00.000 UTCG
Stop:	2 Jul 2020 16:00:00.000 UTCG

4. When you finish, click OK.
5. When the scenario loads, click Save (). A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location and click Save.

Note: Save Often!

View Both the 2D and 3D Graphics Windows

You can view coverage in both the 2D and 3D Graphics windows. Placing them side by side makes this simple to do.

1. Close the Time Line at the bottom of STK.
2. Click Window in the STK menu bar.
3. Select Tile Vertically.

Turn Off Terrain Server

Analytical and visual terrain is not required in this analysis.

1. Open STK_Analyzer's () properties ().
2. Select the Basic - Terrain page.
3. Clear the Use terrain server for analysis option.
4. Click OK to accept the changes, and close the Properties Browser.

Design a Satellite Orbit

Insert a Satellite () object, and place it in a retrograde orbit. Use the Orbit Wizard Orbit Designer which allows you to create a custom orbit.

1. Using the Insert STK Objects tool, insert a Satellite () object using the Orbit Wizard ()method.
2. Set the following:

Option	Value
Type:	Orbit Designer
Satellite Name:	MySat
Semimajor Axis:	10600 km
Eccentricity:	0.363
Inclination:	116 deg
Argument of Perigee:	270 deg
RAAN:	104 deg
True Anomaly:	90 deg

3. Click OK.

Sensor Object

Use a Sensor ( ) object that provides a simple conic, 20 degree, field-of-view. The field of view will simulate a camera's field-of-view.

1. Using the Insert STK Objects tool, insert a Sensor ( ) object using the Define Properties ( ) method.
2. When the Select Object window opens, select MySat ( ).
3. Click OK.
4. On the Basic - Definition page, change the Simple Conic - Cone Half Angle: value to 10 deg.
5. Click OK to accept the changes, and close the Properties Browser.
6. Rename the Sensor ( ) object Camera_View.

Coverage Definition Object

The Coverage Definition object defines a coverage area for analysis. In this instance, you require global coverage.

1. Using the Insert STK Objects tool, insert a Coverage Definition ( ) object using the Insert Default method.
2. Rename the Coverage Definition ( ) object Global_Grid.
3. Open Global_Grid's ( ) properties ( ).

Coverage Grid

Global Coverage grid type creates a grid that covers the entire globe.

1. On the Basic - Grid page, change Grid Area of Interest - Type: to Global.
2. Click Apply to accept the changes, and keep the Properties Browser open.

Coverage Assets

Assets properties allow you to specify the STK objects used to provide coverage.

1. Select the Basic - Assets page.
2. In the Assets list, select Camera_View ( ).
3. Click Assign.
4. Click OK to accept the changes, and close the Properties Browser.

Figures of Merit

A Figure of Merit ( ) object allows you to specify the method by which the quality of coverage is measured.

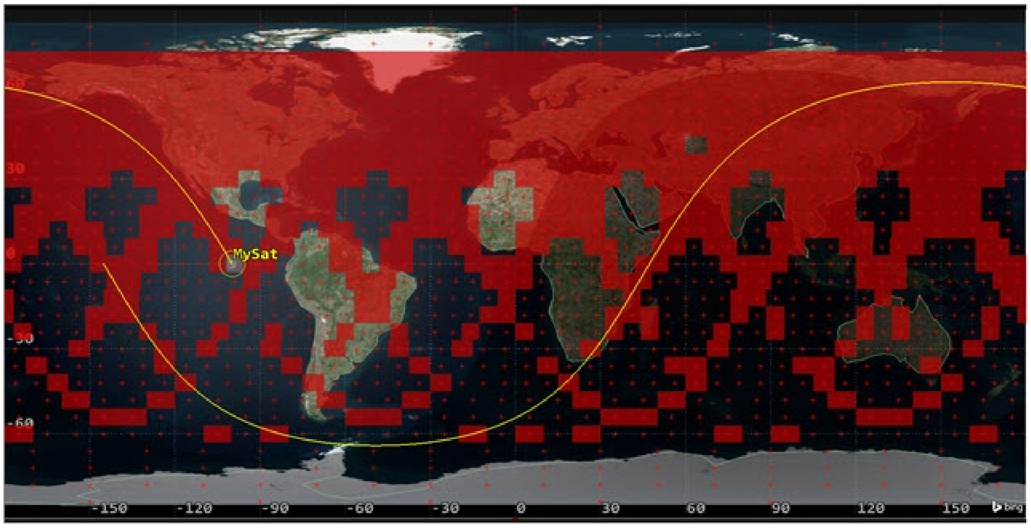
The default Coverage type for a Figure Of Merit ( ) object is simple coverage.

1. Using the Insert STK Objects tool, insert a Figure Of Merit ( ) object using the Insert Default method.
2. When the Select Object window opens, select Global_Grid ( ).
3. Click OK.
4. Rename the Figure Of Merit ( ) object Simple_Cov.

Compute Accesses Tool

The ultimate goal of Coverage is to analyze accesses to an area using assigned assets.

1. Right-click Global_Grid ( ) in the Object Browser.
2. Select CoverageDefinition.
3. Select Compute Accesses.



2D GRAPHICS WINDOW GLOBAL COVERAGE

Percent Satisfied

Percent Satisfied is the percentage of coverage grid area which is satisfied. It's computed by summing the areas associated with all satisfied grid points, dividing by the total grid area and multiplying by 100. In this scenario, you're interested in the Percent Coverage static value of Simple Coverage, meaning the percent of the coverage grid area covered by at least one asset at some point during the coverage interval.

1. Right-click on Simple_Cov ( ) in the Object Browser.
2. Select Report & Graph Manager ( ).
3. When the Report & Graph Manager opens, select the Percent Satisfied report in the Installed Styles list.
4. Click Generate.

5. Note the % Satisfied value at the bottom of the report (e.g. ~49 percent). The value you see is the scenario benchmark.

6. When finished, close the report and the Report & Graph Manager.

Analyzer

Analyzer provides a set of analysis tools that:

- Enable you to understand the design space of your systems.
- Enable you to perform analyses in STK easily, without involving programming or scripting.
- Introduce trade study and post-processing capabilities.
- Can be used with all STK scenarios, including those with STK Astrogator satellites.

Determine the Impact of Satellite Inclination on Percent Satisfied

The first study you will perform varies inclination and its effect on global coverage. You need to select input and output variables from the main *Analyzer* window to pass to the Parametric Study tool.

1. Click View on the STK menu bar.
2. Select Toolbars.
3. Select Analyzer.
4. Click the *Analyzer* ( ) button on the *Analyzer* Tool Bar.

> **Note:** Another way of opening *Analyzer* is to click Analysis on the STK menu bar, select *Analyzer*, and then click the *Analyzer* button. One more way opening *Analyzer* is to go to the Object Browser, right-click on the object (or any object), select the object's Plugins, and click *Analyzer*.

Analyzer Layout

Use the *Analyzer* Main Form to configure input and output variables available for further analysis. You will first select an object in the STK Variables tree on the left. When an object is selected, all possible input variable candidates are listed under the STK Property Variables - General tab and the Active Constraints tab. All output variable candidates are listed under the Data Provider Variable - Data Providers tab and Object Coverage tab.

Input Inclination

Start by selecting Inclination as the Input variable.

1. Select MySat ( ) in the STK Variables tree.
2. Expand (⊞) Propagator (TwoBody) in the STK Property Variables - General tab.
3. Double-click on Inclination to move it to the *Analyzer* Variables field as an Input.

Output Percent Satisfied

The same data providers that are in the Report & Graph Manager are available in the Data Provider Variables list. Select Percent Satisfied as the Output variable.

1. In the STK Variables tree, expand (⊞) Global_Grid ( ).
2. Select Simple_Cov ( ).
3. Expand (⊞) Static Satisfaction in the Data Provider Variables - Data Providers tab.
4. Double-click on Percent Satisfied to move it to the Analyzer Variables field as an Output.

Parametric Study Tool

The **Parametric Study Tool** runs a model through a sweep of values for some input variable. The resulting data can be plotted to view trends.

1. Click Parametric Study... ( ) on the *Analyzer* toolbar to open the Parametric Study Tool.

Inclination Parametric Study

Let's set up a Parametric Study with Inclination as the Design Variable and Percent Satisfied as the Response.

1. Drag and drop the Design Variable, Inclination, from the Component Tree on the left to the Parametric Study Tool on the right.
2. Set the following:

Option	Value
starting value:	112
ending value:	120
step size:	1

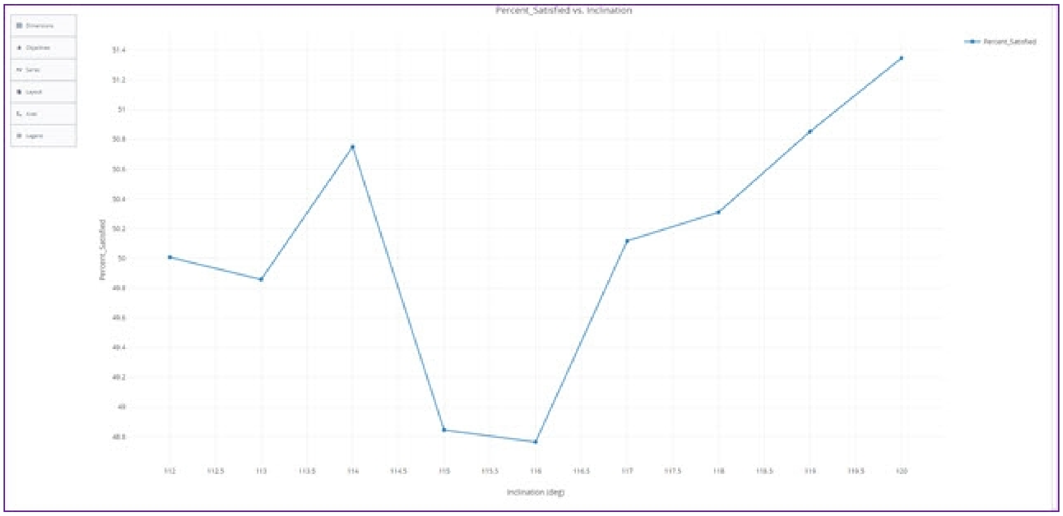
> **Note:** Design Variable units are not specified in *Analyzer*. *Analyzer* assumes the default units set in STK.

3. Notice the number of samples is automatically calculated as nine based on the values we set.
4. Drag and drop the Percent Satisfied data provider element into the Responses field.
5. Click Run...
6. Notice nine runs are performed since the number of samples is set to nine.

Data Explorer

The **Data Explorer** is a Trade Study tool used to display data collected from STK. While data is being collected in the Table, the Data Explorer window displays a progress meter, a halt button, and the data. Once the Parametric study is complete, the **Table page** and **2D Scatter Plot** display the collected data.

1. When the Parametric study is finished, close the 2D Scatter Plot.
2. Select the Table Page - Trade Study 1 - Data Explorer window to bring it to the front.
3. Notice nine runs were performed at 1 deg increments from 112 deg to 120 deg inclination.
4. Notice the second row shows the global coverage percentage for each change in inclination.
5. Note that an inclination of 120 deg provides the highest percentage of global coverage.
6. On the Table Page tool bar, click Add View.
7. Select 2D Line plot.
8. Click Axes.
9. Select the Ticks tab.
10. Change the Max # value to 20.
11. Click anywhere on the plot to close the Axes menu.



2D LINE PLOT INCLINATION

12. Looking at the 2D Line Plot, you see that 120 deg inclination (basing the analysis on one degree increments) gives you the best choice for global coverage during the 24 hour period.
13. Close the 2D Line Plot and the Table Page.
14. Select No when the Save window appears.
15. Close the Parametric Study () window.
16. Return to the *Analyzer* () window.

Input Eccentricity

Eccentricity could have an impact on the sensor's footprint. However, you have to take into consideration the possibility of the satellite impacting the Earth's surface when changing the eccentricity.

1. Select MySat () in the STK Variables tree.
2. In the STK Property Variables - General tab, expand (⊞) Propagator (TwoBody).
3. Double-click on Eccentricity to move it to the *Analyzer* Variables field as an Input.
4. Click the Parametric Study Tool () button on the *Analyzer* toolbar.

Eccentricity Parametric Study

Let's set up a Parametric Study with Eccentricity as the Design Variable and Percent Satisfied as the Response.

1. Drag and drop the Design Variable, Eccentricity, from the Component Tree on the left to the Parametric Study Tool on the right.
2. Set the following:

Option	Value
starting value:	.362
ending value:	.364
number of samples:	10

3. Notice the step size is automatically calculated based on the values we set.
4. Drag and drop the Percent Satisfied data provider element into the Responses field.
5. Click Run...

Data Explorer

The **Data Explorer** is a Trade Study tool used to display data collected from STK. While data is being collected in the Table, the Data Explorer window displays a progress meter, a halt button, and the data. Once the Parametric study is complete, the **Table page** and **2D Scatter Plot** display the collected data.

1. When the Parametric study is finished, close the 2D Scatter Plot.
2. Select the Table Page - Trade Study 2 - Data Explorer window to bring it to the front.
3. On the Table Page tool bar, click Add View.

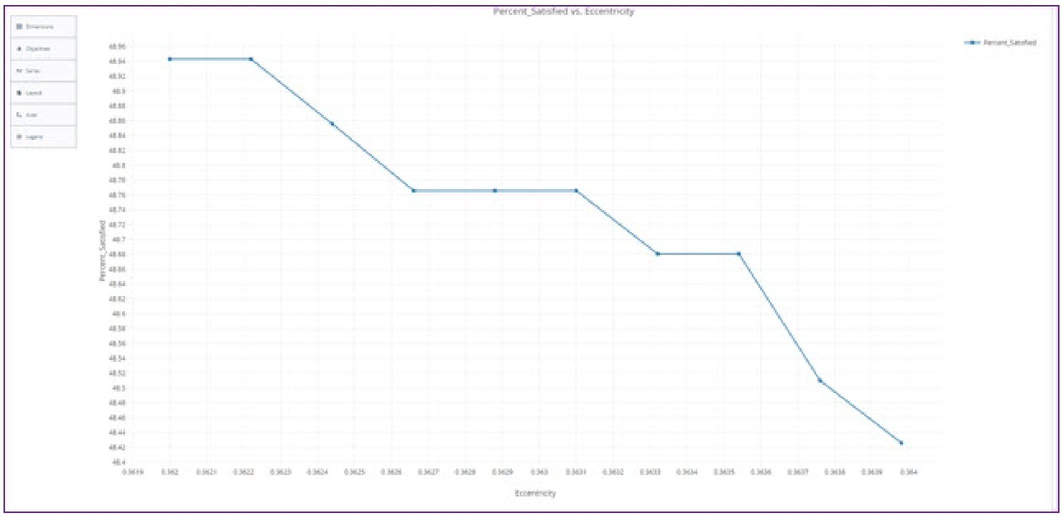
4. Select 2D Line plot.

5. Click Axes.

6. Select the Ticks tab.

7. Change the Max # value to 40.

8. Click anywhere on the plot to close the Axes menu.



2D LINE PLOT ECCENTRICITY

The small change in Eccentricity didn't have too much impact on global coverage. 0.362000 through 0.362220 provided a steady value of 48.9433 percent satisfied. After that, there is a steady drop in percentage.

9. Place your cursor over one of the points. A small window will appear with analytical information concerning the point.

10. Close the 2D Line Plot and the Table Page.

11. Select No when the Save window appears.

12. Close the Parametric Study ( ) window.

13. Return to the *Analyzer* ( ) window.

Carpet Plot Tool

A **Carpet Plot** is a means of displaying data dependent on two variables in a format that makes interpretation easier than normal multiple curve plots. A Carpet Plot can be thought of as a multi-dimensional Parametric Study.

1. To access the Carpet Plot Tool ( ), click Carpet Plot... on the *Analyzer* toolbar.

Carpet Plot

Let's set up a Carpet Plot with Inclination and Eccentricity as the Design Variables and Percent Satisfied as the Response. Setting the design variables is similar to using the Parametric Study Tool except you now have two variables instead of one.

1. Drag and drop Inclination from the Component Tree on the left to the first Design Variable field on the right.
2. Drag and drop Eccentricity from the Component Tree on the left to the second Design Variable field on the right.
3. Set the following Inclination Design Variable:

Option	Value
From	119
To	121
Step Size	1

4. Set the following Eccentricity Design Variable:

Option	Value

From	.361
To	.365
Step Size	0.001

5. Drag and drop the Percent Satisfied data provider element into the Responses field.

6. Click Run.

The Best Combination

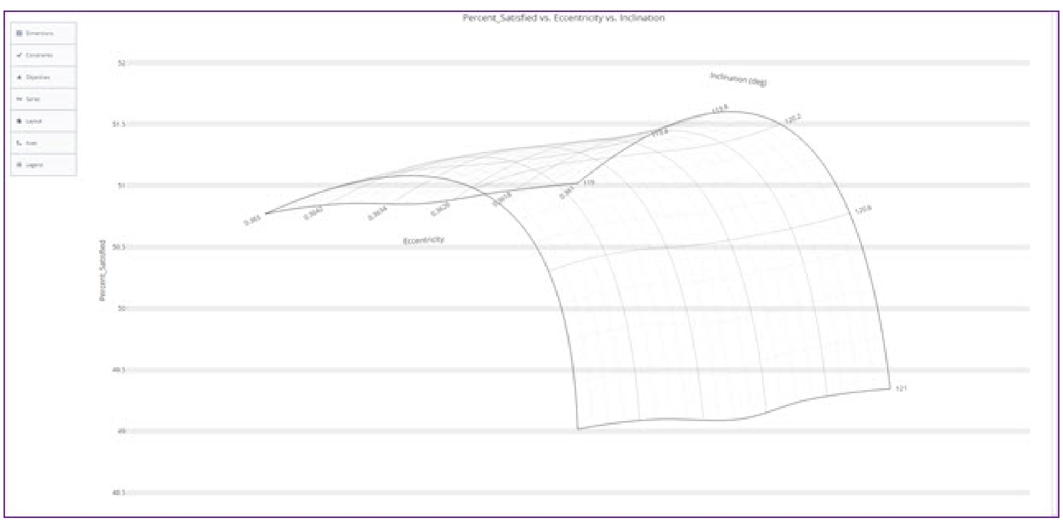
Using the Carpet Plot Tool, look for the best combination of Inclination and Eccentricity. First, you will make the Carpet Plot easier to read, then look at the data.

1. Click Axes.

2. Select the Lines tab.

3. Change the Grid Lines value to 10.

4. Click anywhere on the plot to close the Axes menu.



The original benchmark of global coverage was approximately 49 percent. In this study, an Inclination of 120 degrees and an Eccentricity of 0.361 provided the best percentage of global coverage of approximately 51.6 percent.

5. When finished, close the Carpet Plot and the Table Page.
6. Select No when the Save window appears.
7. Close the Carpet Plot Tool ( ) window.
8. Close *Analyzer* ( ).

Save Your Work

Always remember to save your scenario!

1. Save ( ) your work.

Summary

You began the scenario by placing a Satellite ( ) object in a retrograde orbit. You attached a Sensor ( ) object to the Satellite ( ) with a 20 degree field of view and orientated to point straight down below the Satellite ( ) to the Earth's surface. Using a Coverage Definition ( ) object, you created a global grid and assigned the Sensor ( ) object as the asset. Using a Figure Of Merit ( ) object and Simple Coverage, you determined that approximately 49 percent of the Earth's surface was accessed by the Sensor ( ) object during a 24 hour analysis period. The Satellite's ( ) original Inclination was 116 degrees and its Eccentricity was 0.363. Using *Analyzer*, you ran two Parametric studies changing Inclination and Eccentricity and studied their effects on global coverage. You ended the analysis by running a Carpet Plot study which determined the best combination of Inclination and Eccentricity that provided the highest percentage of global coverage. Your final value for

Inclination was 120 degrees and Eccentricity was 0.361. This combination raised global coverage percentage from the benchmark of approximately 49 percent to 51.6 percent.

On Your Own

You could rerun all the Parametric studies using new values with the existing input variables. You could add new inputs such as Semi Major Axis, and study how that affects coverage. A different approach might be to add an input that changes the cone half angle of the Sensor ( ) object. There are a lot of combinations you could try. Explore and have fun!

Part 11: Introduction to Communications

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- Communications

Problem Statement

Engineers and operators need to quickly determine communication link budgets. Factors such as communications unobstructed or obstructed by terrain, trees or man made structures need to be taken into consideration. Other factors that need to be included and analyzed are rain models, atmospheric losses, and RF interference sources. In this scenario, a team of scientists is monitoring glacial meltwater in a remote, mountainous location. Prior to setting up camp, they need to determine how their location will impact a link budget between them and a low earth orbit (LEO), Earth observation satellite which is downloading data to the team.

Solution

Use STK Pro and STK's *Communications* capability to model and analyze a link budget between the ground site and the Earth observation satellite. The satellite transmitter will be analyzed using an isotropic, omnidirectional antenna pattern. The ground team will employ a small parabolic antenna steered by a servo motor that can track the satellite. After establishing a link budget based on line of sight only, terrain obstruction, rain, atmospheric absorption and system noise temperature will be factored in until the final link budget analysis is complete.

What You Will Learn

Upon completion of this tutorial, you will understand:

- Receiver and Transmitter objects
- STK Antenna models
- RF Environment properties
- Simple and detailed link budgets

Create a New Scenario

Create a new scenario for a twenty four (24) hour time period starting 1 Jul 2020 06:00:00.000 UTCG.

1. Launch STK ( ).
2. In the Welcome to STK window, click Create a Scenario.
3. Enter the following in the New Scenario Wizard:

Option	Value
Name:	STK_Communications
Location:	Default
Start:	1 Jul 2020 06:00:00.000 UTCG
Stop:	2 Jul 2020 06:00:00.000 UTCG

4. When you finish, click OK.
5. When the scenario loads, click Save (). A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location and click Save.

Note: Save Often!

Add Analytical and Visual Terrain

An STK Terrain File (pdtt) located in the STK install area will be used for analysis and situational awareness in the 3D Graphics window.

1. Right-click on STK_Communications () and select Properties ().
2. Select the Basic - Terrain page.
3. Disable Use terrain server for analysis.
4. Click OK to accept the changes and close the Properties Browser.
5. Bring the 3D Graphics window to the front.
6. In the 3D Graphic window toolbar, click Globe Manager ().

7. In the Globe Manager's Hierarchy toolbar, click Add Terrain/Imagery ( ).
8. Select the Add Terrain/Imagery ( ) option in the drop-down.
9. In the Globe Manager: Open Terrain and Imagery Data window, click the ellipsis button ( ) in the Path field.
10. Navigate to <STK Install Folder>\Data\Resources\stktraining\imagery (e.g. This PC then C:\Program Files\AGI\STK 12\Data\Resources\stktraining\imagery).
11. Click OK.
12. Select RaistingStation.pdtt.
13. Click Add .
14. When the Use Terrain for Analysis prompt displays, click Yes to enable terrain for analysis.

Declutter the Labels

Label Declutter is used to separate the labels on objects that are in close proximity for better identification in small areas.

1. Bring the 3D Graphics window to the front.
2. Open the 3D Graphics window properties ( ).
3. On the Details page, locate the Label Declutter section.
4. Select Enable.
5. Click OK to accept the changes and close the Properties Browser.

Insert the Earth Observation Satellite

The Earth observation satellite is in a sun-synchronous orbit. Sun-synchronous orbits are designed to utilize the effect of the Earth's oblateness, causing the orbit plane to precess at a rate equal to the mean orbital rate of the Earth around the Sun. Sun synchronous orbits have the property that their nodes maintain constant local mean solar times.

1. Using the Insert STK Objects tool, insert a Satellite ( ) object using the From Standard Object Database method.
2. In the Search Standard Object Data window, enter Rapideye in the Name or ID: field.
3. Click Search.
4. In the Results: field, select RapidEye 2 using the AGI's Standard Object Data Service Data Source.
5. Click Insert.
6. Close the Search Standard Object Data window.

Insert the Scientists' Camp Site

The camp site sits in a valley next to a river being fed by mountain glaciers.

1. Using the Insert STK Objects tool, insert a Place ( ) object using the Define Properties method.
2. On the Basic - Position page, set the following:

Option	Value
Latitude:	47.5605 deg
Longitude:	11.5027 deg

Height Above Ground:	6 ft (simulates antenna height)

3. Click OK to accept the changes and close the Properties Browser.
4. Rename the Place ( ) object Camp_Site.

Simple Transmitter Model

The **Simple Transmitter** model is convenient when you do not have all the information necessary to model the transmitter in detail; for example, during the system engineering process.

1. Using the Insert STK Objects tool, insert a Transmitter ( ) object using the Insert Default method.
2. When the Select Object window appears, select Rapideye2_33312 ( ).
3. Click OK.
4. Rename the Transmitter ( ) object Download_Tx.

Transmitter Model Specs

Using a Simple Transmitter Model type, the Model Specs tab allows you to set the transmitter's frequency, EIRP (Effective Isotropic Radiated Power), data rate, and polarization. The Simple Transmitter model defaults to an isotropic antenna pattern. An isotropic antenna pattern is an ideal spherical pattern antenna with constant gain.

1. Open Download_Tx's ( ) properties.
2. On the Basic - Definition page, ensure the Model Specs tab is selected.
3. Set the following:

Option	Value
Frequency:	1.7045 GHz
EIRP:	10 dBW
Data Rate:	4.2 Mb/sec

4. Select Use in the Polarization field.

5. Set the polarization to Right-hand Circular.

6. Click OK to accept the changes and close the Properties Browser.

> **Note:** The default modulation for the Transmitter ( ) object is Bi-phase shift keying (BPSK). Additional Gains and Losses is used to model gains and losses that affect performance but are not defined using built-in analytical models.

Receiver Antenna Orientation

The receiver antenna is steerable. To create a steering device (e.g. servo motor) in STK, you use a Sensor ( ) object.

1. Zoom To Camp_Site ( ).

2. Using the Insert STK Objects tool, insert a Sensor ( ) object using the Insert Default method.

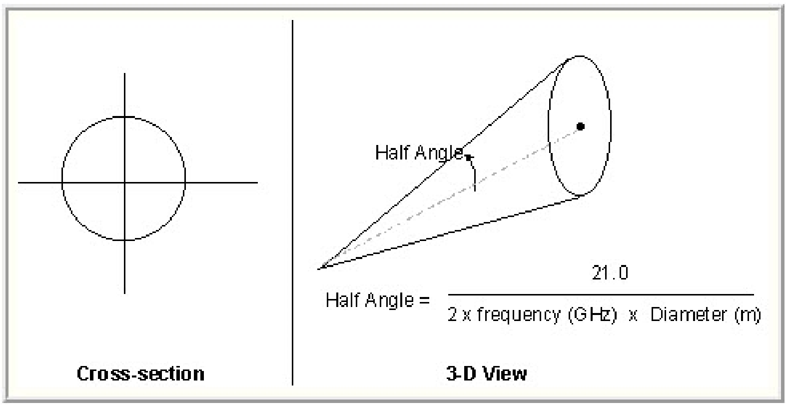
3. When the Select Object window appears, select Camp_Site ( ).

4. Click OK.

5. Rename the Sensor ( ) object Servo_Motor.

Half Power Sensor Patterns

Half Power sensor patterns are designed to visually model parabolic antennas. The sensor half angle is determined by frequency and antenna diameter.



HALF POWER SENSOR

1. Open Servo_Motor's properties ().
2. On the Basic - Definition page, set the following:

Option	Value
Sensor Type:	Half Power
Frequency:	1.7045 GHz
Diameter:	1.6 m

3. Click Apply to accept the changes and keep the Properties Browser open.

Targeted Sensor

The Targeted pointing type causes the sensor to point to other objects in the scenario.

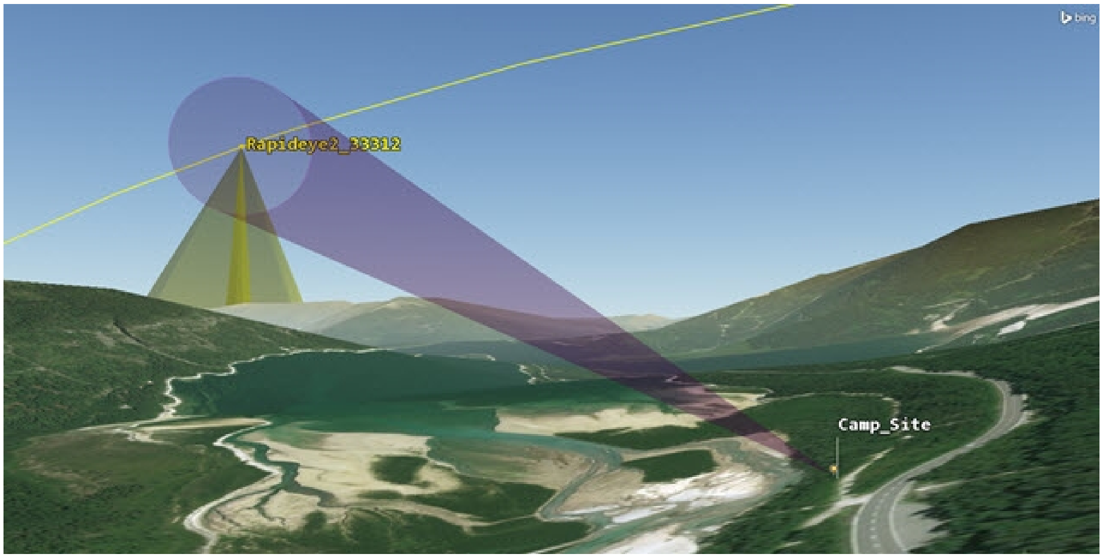
1. Select the Basic - Pointing page.
2. Set the Pointing Type: to Targeted.
3. Set the Track Mode: value to **Receive**.
4. Move ( ) Rapideye2_33312 ( ) from the Available Targets list to the Assigned Targets list.
5. Click Apply to accept the changes and keep the Properties Browser open.

Target Times

Use **Target Times** to schedule or view access times from the sensor to the selected targets. This is a quick way to determine an access without using the Access Tool.

1. Click Target Times.
2. There are seven (7) opportunities to download data from the satellite to the ground site.
3. Click Cancel to close the Target Times window.
4. Click OK to close Servo_Motor's ( ) properties.
5. Bring the 3D Graphics window to the front.
6. In the Timeline View, slowly move the gray pointer until the sensor accesses the satellite. Use your mouse to change the view so that you can view the access between Servo_Motor ( ) and Rapideye2_33312 ( ).

   You can see that Servo_Motor ( ) is targeting Rapideye2_33312 ( ). Rapideye2_33312 ( ) has two (2) Sensor ( ) objects attached to it that were downloaded with the Satellite ( ) object if the satellite was inserted from AGI's Standard Object Data Service Data Source.



SENSOR TARGETING SATELLITE

Complex Receiver Model

The Complex Receiver model allows you to select among a variety of analytical and realistic antenna models, and to define the characteristics of the selected antenna type.

1. Using the Insert STK Objects tool, insert a Receiver ( ) object using the Insert Default method.
2. When the Select Object window appears, select Servo_Motor ( ).
3. Click OK.
4. Rename the Receiver ( ) object Download_Rx.

Receiver Model Specs

1. Open Download _Rx's ( ) properties ( ).
2. On the Basic - Definition page, click the ellipsis button (Component Selector) ( ) beside the Type field.

3. Select Complex Receiver Model.

4. Click OK.

By default, the frequency is set to Auto Track. The Frequency Auto Track option allows a receiver to track and lock onto the transmitter's carrier frequency with which it is currently linking, including any Doppler shift. LNA refers to Low Noise Amplifier. If you have those specifications, you can add them.

Receiver Antenna

You can select to embed an **antenna model** from the Component Browser or you can link to an antenna object. You will use a **parabolic antenna**.

1. Select the Antenna tab.

2. Click the ellipsis button (Component Selector) (...) beside the Type field.

3. Select Parabolic.

4. Click OK.

5. Set the following:

Option	Value
Design Frequency:	1.7 GHz
Diameter:	1.6 m

6. Click Apply to accept the changes and keep the Properties Browser open.

Receiver Antenna Polarization

The receiver **polarization type** is the same as the transmitter's polarization.

1. Select the Polarization sub-tab.
2. Select Use.
3. Change the polarization to Right-hand Circular.
4. Click OK to accept the changes and close the Properties Browser.

Simple Link Budget

Creating a Link Budget in the Access tool is referred to as a Simple Link Budget. The **Link Budget Report** is a specialized Access Report for basic link budget analysis and is available using the Link Budget button in the Reports frame of the Access window.

1. In the Object Browser, right click on Download_Rx ( ) and select Access ( ).
2. When the Access Tool opens, in the Associated Objects list, expand ( ) Rapideye2_33312 ( ).
3. Select Download_Tx ( ).
4. Click Compute (Compute).
5. In the Reports section, click Link Budget...

   Take some time to look at the Simple Link Budget report. As the satellite rises over the horizon of the central body (WGS84) you receive transmissions. When the satellite falls below the horizon, you lose transmissions.

6. Leave the Link Budget Report open.

Take Terrain Into Consideration

Use **Terrain Mask**. If this check box is selected, access to the object is constrained by any terrain data in the line of sight to which access is being calculated.

1. Open Download_Rx's () properties ().

2. Select the Constraints - Basic page.

3. Select Terrain Mask.

4. Click OK to accept the changes and close the Properties Browser.

5. Return to the Link Budget Report and click Refresh (F5) ().

   You'll see that all accesses blocked by analytical terrain (RaistingStation.pdtt) have been removed from the report. You began with seven (7) accesses but taking terrain into account you now have four (4) accesses.

6. Close the Link Budget Report.

7. Return to the Access Tool.

Detailed Link Budget

The Detailed Link Budget Report is a modified Link Budge Report with added **Access Data Provider Elements**.

1. In the Access Tool, click Report & Graph Manager...

2. When the Report & Graph Manager opens, go to the Styles - Installed Styles list and select Link Budget - Detailed.

3. Click Generate.

4. Change the report Step: to 30 sec.

5. Press Enter on your keyboard.

   Take some time to look at the report. Looking at the first access, note the values for Atmos Loss (dB) and Rain Loss (dB). They're currently zero (0). You haven't loaded any RF Environment models. Also note the values in the C/N (dB) (carrier to noise ratio), Eb/No (dB) (energy per bit to noise ratio), and BER (Bit Error Rate) columns. For the purposes of your analysis due to downloading data, you require a BER equal to or lower than 1.000000e-13. You can see from the report that you only have a few minutes during each pass to download data.

6. Leave the report open.

Rain Model

Environmental factors can affect the performance of a communications link. Apply rain and atmospheric absorption models to the analysis. Rain models are used to estimate the amount of degradation (or fading) of the signal when passing through rain.

1. Open STK_Communications ( ) properties ( ).
2. Select the RF - Environment page.
3. Select the Rain & Cloud & Fog tab.
4. Select Use In the Rain Model section. Leave the default ITU (International Telecommunication Union) model.
5. Click Apply to accept the changes and keep the Properties Browser open.

Atmospheric Absorption Model

Atmospheric Absorption models estimate the attenuation of atmospheric gases on terrestrial and slant path communication signals.

1. Select the Atmospheric Absorption tab.
2. Select Use. Leave the default ITU model.
3. Click OK to accept the changes and close the Properties Browser.
4. Return to the Link Budget - Detailed report.

5. Observe the C/N (dB), Eb/No (dB) and BER columns.
6. Click Refresh (F5) ( ). There was a slight change in the C/N (dB) and Eb/No (dB) values.
7. Scroll to the Atmos Loss (dB) and Rain Loss (dB) columns.

   Losses were minimal, therefore the slight losses in C/N (dB) and Eb/No (dB) values.
8. Leave the report open.

System Noise Temperature

The Receiver's **System Noise Temperature** allows you to specify the system's inherent noise characteristics.

1. Open Download_Rx's ( ) properties ( ).
2. On the Basic - Definition page, select the System Noise Temperature tab.
3. Select Compute.
4. Select Compute in the Antenna Noise section.
5. Select Sun, Atmosphere, Rain and Cosmic Background.
6. Click OK to accept the changes and close the Properties Browser.
7. Return to the Link Budget - Detailed report.
8. Observe the C/N (dB), Eb/No (dB) and BER columns.
9. Click Refresh (F5) ( ). There were increases in the C/N (dB) and Eb/No (dB) values and decreases in BER.
10. Look at the following columns and observe their values:
    - Tatmos (K)
    - Train (K)

- Tsun (K)
- Tearth (K)
- Tcosmic (K)
- Tantenna (K)
- Tequivalent (K)

These are the calculated noise temperatures. Calculating system noise temperature improved your Link Budget Report and extended the time available for downloading data.

Summary

You inserted a Place ( ) object into the scenario which simulated the location of a scientific team monitoring glacial meltwater in mountainous terrain. You used a local terrain file both analytically and visually for your analysis and situational awareness. You inserted and propagated an actual Earth Observation Satellite ( ) object which the scientists need to communicate with for data download. You were introduced to the Simple Transmitter Model which was attached to the Satellite ( ) object. The Simple Transmitter uses an isotropic antenna. Next, you created a servo motor using a Sensor ( ) object which was used to steer the ground site receiver antenna by locking onto the Satellite ( ) object. The Receiver ( ) object used a Complex Receiver Model. This model allowed you to input a Parabolic Antenna Pattern. The first analysis, using the Access Tool, focused on a Simple Link Budget. The only constraint applied was line of sight which is basically horizon to horizon using the central body. Next, using Terrain Mask, you took into account local terrain and lost multiple accesses to the Satellite ( ) object. You moved to the Report & Graph Manager and generated a Detailed Link Budget. You enabled an ITU rain model and atmospheric absorption model which had a slight detrimental impact on the Link Budget Report. Finally, you added System Noise Temperature analysis to the Link Budget Report which had a positive impact to the link budget.

Save Your Work

1. Close any open reports, properties and the Report & Graph Manager.
2. Save ( ) your work.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information concerning Transmitter ( ) and Receiver ( ) objects. Now's a good time to go back through this tutorial and view that information.

For further study:

Modulator

Communications allows you to select from multiple modulators, including user-defined modulators. Each modulator has a defined modulation. Normally, you'll perform this function in the Transmitter ( ) object. The Receiver ( ) object defaults to the same modulation as the Transmitter ( ) object when calculating a Link Budget Report. However, you can override this.

1. Select the Modulator tab.
2. To understand the settings on this page, click **HERE**.

Additional Gains and Losses

During communications analyses, it is often necessary to model gains and losses that affect performance but are not defined using built-in analytical models. STK allows you to model these by specifying miscellaneous gains and losses that can be added to the equation. This can be found in both the Transmitter ( ) and Receiver ( ) objects.

1. Select the Additional Gains and Losses tab.
2. To understand the settings on this page, click **HERE**.

Part 12: Introduction to Radar

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- Radar

Problem Statement

Engineers and operators need to determine how various radar settings will affect its ability to track different sized targets.

They want to know how the following settings affect a radar's ability to track multiple target types:

- Radar Cross Section
- Pulse Repetition Frequency
- Gain
- Pulse integration

Solution

Use STK Pro and STK's *Radar* capability to:

1. Create an airfield radar site
2. Model an airport surveillance radar
3. Build a monostatic radar
4. Test various settings against multiple targets
5. Determine probability of detection

What You Will Learn

Upon completion of this tutorial, you will understand:

- Radar Cross Sections
- Monostatic Radars and their settings
- Radar Data Providers

Create a New Scenario

Create a new scenario.

1. Launch STK ( ).
2. Click Create a Scenario ( ) in the Welcome to STK window.

3. Enter the following in the New Scenario Wizard:

Option	Value
Name:	STK_Radar
Location:	Default
Start:	1 Oct 2020 03:00:00.000 UTCG
Stop:	+30 min

4. When finished, click **OK** .
5. When the scenario loads, click Save ( ). A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location in the Save As window.
7. Click **Save** .

Note: Save Often!

Turn Off Terrain Server

This is an introduction to *Radar*. Terrain will not be used in this analysis.

1. Open STK_Radar's ( ) properties ( ).
2. Select the Basic - Terrain page.
3. Clear Use terrain server for analysis.
4. Click **OK** to accept the changes and close the Properties Browser.

Turn On Label Declutter

Turn on Label Declutter to reposition object labels so they do not obstruct one another while in close proximity.

1. Open the 3D Graphics Window's properties ().
2. Select the Details page.
3. Select Enable for Label Declutter.
4. Click OK .

Insert the Target Aircraft

Insert an **Aircraft** () object. We will use the aircraft to analyze the airfield surveillance radar.

1. Select Aircraft () in the Insert STK Objects tool.
2. Select the Insert Default method.
3. Click Insert... .
4. Rename the Aircraft () Target_Acft.

Create the Target Aircraft's Route

Create Target_Acft's () route, then modify it's altitude and speed.

1. Open Target_Acft's () properties ().
2. Select the Basic - Route page.

3. Click Insert Point two times.

4. Set the following:

Waypoint	Latitude	Longitude
One	37 deg	139.7 deg
Two	34 deg	139.1 deg

5. Click Set All... .

6. Select Altitude: and Speed: in the Set All Grid Values window.

7. Set the following:

Option	Value
Altitude:	25000 ft
Speed:	330 mi/hr

8. Click OK to close the Set All Grid Values window.

9. Click Apply to accept the changes and keep the Properties Browser open.

Specify the Radar Cross Section

Before setting up and constraining a radar system, *Radar* allows you to specify an important property of a potential radar target - its radar cross section (RCS). Use the RCS of a popular four engined transport turboprop aircraft.

1. Select the RF - Radar Cross Section page.

2. At the top of the page, clear Inherit. This allows you to set the RCS settings for the Aircraft () instead of inheriting the settings from the Scenario () object.

3. Set the Constant RCS Value: to 19 dBsm (decibels referenced to a square meter).

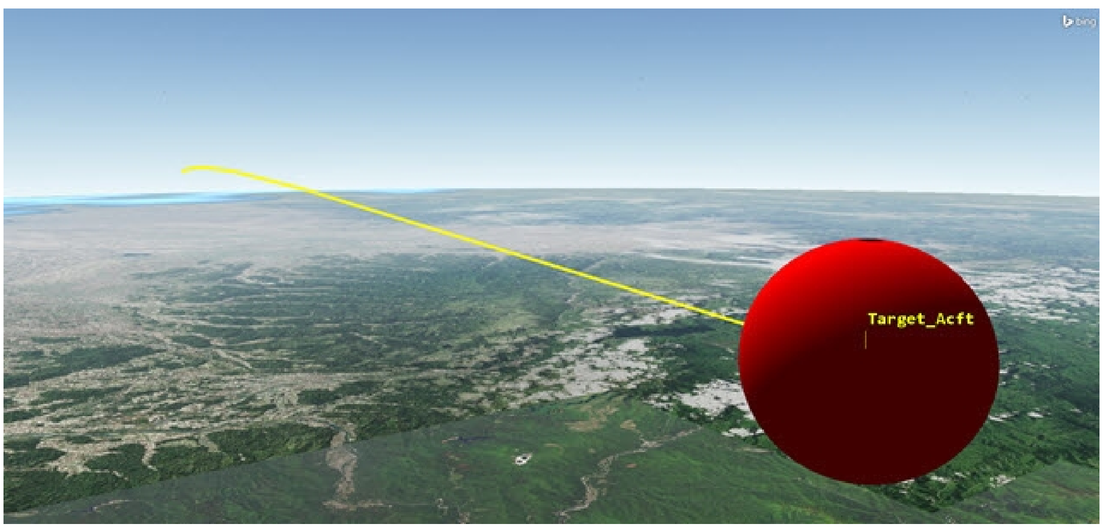
   Ideally, you would want to use an Aspect Dependent RCS file. Since you don't have one, you will use a constant value. The constant value we set is the RCS of a sphere that radiates isotropically.

4. Click Apply .

Display Radar Cross Section Graphics

The 3D Graphics RCS page allows you to control the 3D display of Radar Cross Section contour lines.

1. Select the 3D Graphics - Radar Cross Section page.
2. Select Show Volume in the Volume Graphics section.
3. Click OK .
4. Bring the 3D Graphics window to the front.
5. Right-click on Target_Acft ( ) in the Object Browser.
6. Select Zoom To.
7. Use your mouse to zoom out until you can see the RCS sphere.



Radar Cross Section Sphere

Insert the Radar Site

Use a **Place** ( ) object as the radar site location.

1. Select Place ( ) in the Insert STK Objects tool.
2. Select the Insert Default method.
3. Click Insert... .
4. Rename the Place ( ) Radar_Site.

Define the Radar Site's Location

Define the location of Radar_Site ( ), and raise its height above ground 50 ft to model the radar antenna height.

1. Open Radar_Site's ( ) properties ( ).
2. Select the Basic - Position page.
3. Set the following:

Option	Value
Latitude:	35.7517 deg
Longitude:	139.3562 deg
Height Above Ground:	50 ft

4. Click OK .

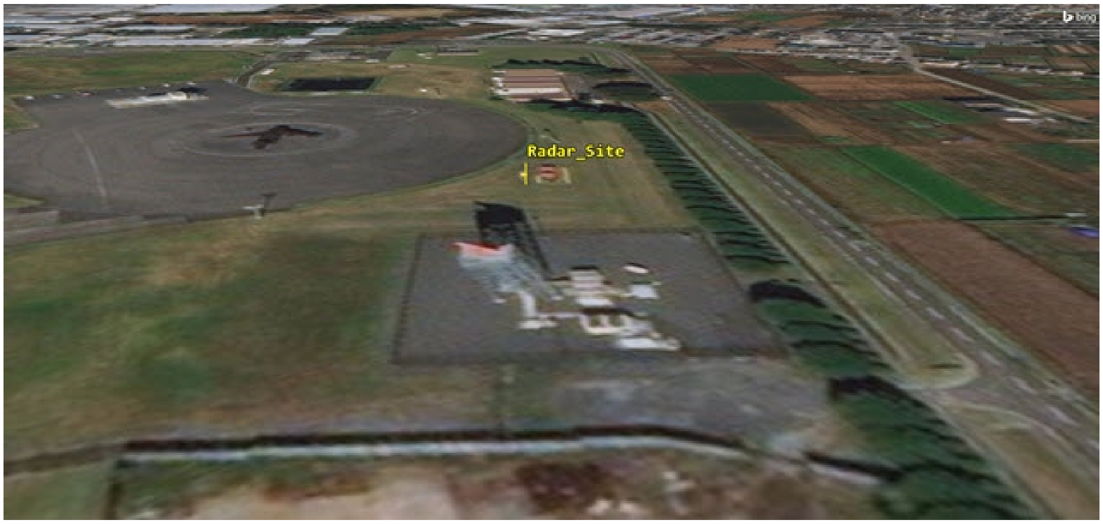
Raising the Place ( ) object 50 feet above the ground simulates the height of the radar antenna.

5. Bring the 3D Graphics window to the front.

6. Right-click on Radar_Site ( ) in the Object Browser.

7. Select Zoom To.

8. Use your mouse to obtain situational awareness of the radar site's location.



Radar Site

Insert the Antenna Servo System

Insert a **Sensor ( ) object** to simulate a servo system for antenna positioning. In STK, you could create a **spinning sensor** to simulate a spinning radar antenna normally seen at an airfield. However, you will lock the sensor onto the aircraft and constrain the sensor to point in a limited area. This simulates the actual field of view of the airfield surveillance radar both horizontally and vertically.

1. Select Sensor ( ) in the Insert STK Objects tool.

2. Select the Insert Default method.

3. Click Insert... .

4. Select Radar_Site ( ) in the Select Object window.

5. Click OK .
6. Rename the Sensor ( ) Servo_System.

Define the Sensor Field of View

Define Servo_System's ( ) 3 degree field of view using a **Simple Conic** sensor pattern. You will use the sensor's field of view for situational awareness when Servo_System( ) points the antenna at a target.

1. Open Servo_System's ( ) properties ( ).
2. Select the Basic - Definition page.
3. Set the Simple Conic - Cone Half Angle: value to 3 deg.
4. Click Apply .

Target the Aircraft

Use the **Targeted** pointing type to point Servo_System ( ) to Target_Acft( ).

1. Select the Basic - Pointing page.
2. Set the Pointing Type: to Targeted.
3. Select Target_Acft ( ) in the Available Targets list.
4. Move ( ) Target_Acft ( ) to the Assigned Targets list.
5. Click Apply .

Set Range and Elevation Angle Constraints

There are many types of radar systems. A typical airport surveillance radar's nominal range is 60 miles and the elevation angle of the beam can track from 0 to 30 degrees. Anything higher than 30 degrees is the cone of silence in which the radar cannot track the aircraft. Extend the Servo_System's ( ) maximum range further than 60 miles in order to lock onto the aircraft when it's above the horizon.

1. Select the Constraints - Basic page.
2. Select Min: and Max: in the Elevation Angle section.
3. Set the Min: value to 0 deg.
4. Set the Max: value to 30 deg.
5. Select Max: in the Range section.
6. Set the value to 150 km.
7. Click **OK** .

Determine Access

Determine when Servo_System ( ) accesses Target_Acft ( ). This will give you a good idea of when the radar may be able to track the aircraft.

1. Right-click on Servo_System ( ) in the Object Browser.
2. Select Access ( ).
3. When the Access Tool opens, select Target_Acft ( ) in the Associated Objects list.
4. Click **Compute** .

5. Click **Access...** in the Reports section.
6. Click Report Units (icon) in the Access report's toolbar.
7. Select Time Dimension in the Units: Access window.
8. Select Minutes (min) in the New Unit Value list.
9. Click **OK** to close the Units: Access window.

   There are two accesses with a total duration of approximately 31 minutes.
10. Close the report.

Generate an Azimuth Elevation Range Report

You have three constraints: a maximum elevation angle of 30 degrees, a minimum elevation angle of 0 degrees, and a maximum range of 150 km. Generate an azimuth-elevation-range (AER) report to see what affect these constraints have on your access report.

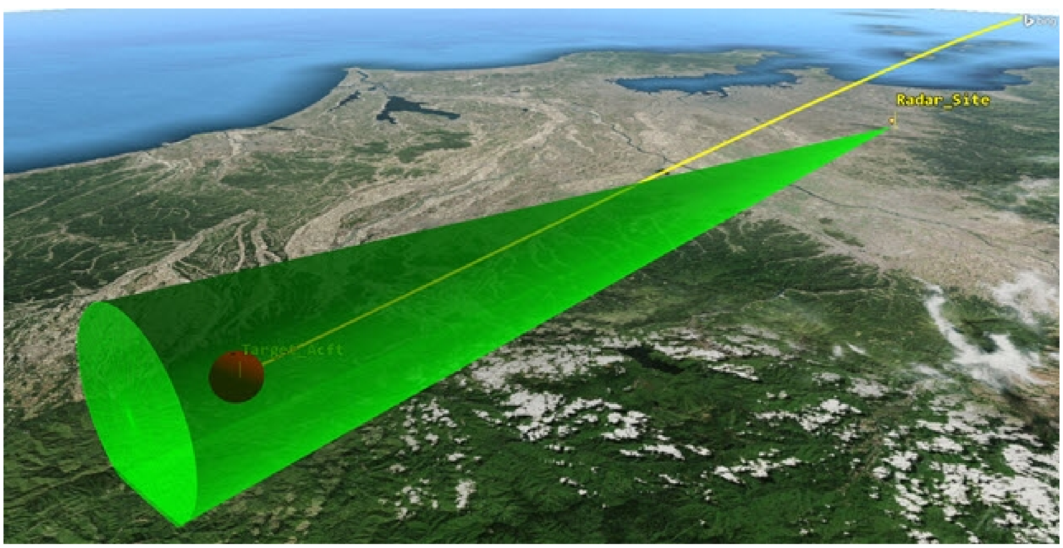
1. Return to the Access Tool.
2. Click **AER...** in the Reports section.
3. Look at the Elevation (deg) column.
4. Notice that the first access ends and the second access begins at an approximate elevation angle of 30 degrees.

   There is a break in access when the elevation angle exceeds 30 degrees due to the modeled cone of silence.
5. When finished, close the AER report.
6. Close the Access Tool.

Look at the Sensor's Field of View

Animate through the scenario to get a visual idea of when Servo_System ( ) tracks Target_Acft ( ).

1. Bring the 3D Graphics window to the front.
2. Click Reset ( ) in the Animation Toolbar.
3. Right-click on Radar_Site ( ).
4. Select Zoom To.
5. Use your mouse to zoom out until you can see the entire aircraft flight route, the radar site, and the sensor's field of view.



Sensor Field of View

6. Click Decrease Time Step ( ) in the Animation Toolbar until Time Step: is 3.00 sec.
7. Click Start ( ) in the Animation Toolbar to animate the scenario.
8. Watch the animation. You can see the sensor turn off when the elevation angle exceeds 30 degrees, and

turn back on when it returns to 30 degrees.

9. When finished, click Reset () in the Animation Toolbar.

Insert an Airport Surveillance Radar

Insert a ***Radar* () object** to create an airport surveillance radar. We will model actual airport surveillance radar specifications that are easily available to the public.

1. Select *Radar* () in the Insert STK Objects Tool.
2. Select the Insert Default method.
3. Select Servo_System () in the Select Object window.
4. Click OK .
5. Rename the *Radar* () ASR.

Model a Monostatic Radar

Model a **Monostatic** radar with a **Search/Track** mode. This will model a common antenna for both transmitting and receiving, and detect and track point targets.

> **Note:** To understand constants and equations used in STK, look at **Search/Track Radar Constants and Equations** in STK Help.

1. Open ASR's () properties ().
2. Select the Basic - Definition page.
3. Note that Type: defaults to Monostatic.
4. Note that Mode - Type: defaults to Search Track.

Define the Waveform

The waveform in our system will use a fixed pulse repetition frequency (PRF), with a PRF of ~1000 Hz. Radar systems often use **multiple pulse integration** to increase the signal-to-noise ratio. The PRF is the number of pulses of a repeating signal in a specific time unit. After producing a brief transmission pulse, the transmitter is turned off in order for the receiver to hear the reflections of that signal off of targets.

1. Return to ASR's ( ) properties ( ), Basic - Definition page.
2. Note the Waveform is set to Fixed PRF.
3. Note the default value of 0.001 MHz. We will keep that value since our system's PRF is ~1000 Hz.

Define the Pulse Width

Pulse width is the width of the transmitted pulse (the uncompressed RF bandwidth can also be taken as the inverse of the Pulse Width). Set the pulse width to one microsecond.

1. Return to ASR's ( ) properties ( ), Basic - Definition page.
2. Click the units ( ) drop down next to Pulse Width.
3. Select usec.
4. Set the Pulse Width value to 1 usec.
5. Click **Apply** .

Define the Antenna Pattern

Model the antenna using the **cosine squared aperture rectangular antenna** pattern. The antenna transmit frequency for this radar is between 2.7-2.9 GHz.

1. Select the Antenna tab on ASR's ( ) properties ( ), Basic - Definition page.
2. Click the ellipsis button (Component Selector) ( ) beside the Type field.
3. Select Cosine Squared Aperture Rectangular.
4. Click OK .
5. Select Use Beamwidth.
6. Set the following:

Option	Value
X Dim Beamwidth:	5 deg
Y Dim Beamwidth:	1.4 deg
Design Frequency:	2.8 GHz
Main-lobe Gain: (if required, turn off Computed)	34 dB
Efficiency:	55 %

7. Click Apply .

Define the Radar Transmitter

The transmitter has a frequency range of 2.7-2.9 GHz, a peak power of 20 kW, and uses either linear or circular polarization. We will model linear polarization.

1. Select the Transmitter tab on ASR's ( ) properties ( ), Basic - Definition page.
2. Select Frequency.
3. Set the value to 2.8 GHz.
4. Set the Power: value to 20 kW.
5. Select the Polarization sub-tab.

6. Select Use.

7. Keep the default setting of Linear.

8. Click Apply .

Set the Radar Receiver's Polarization

You don't have specific values regarding the low noise amplifier settings. These would be applied on the Receiver's Specs sub-tab. However, you know the polarization and want to add the receiver's system noise temperature. Let's set the polarization model type to Linear now.

1. Select the Receiver tab on ASR's ( ) properties ( ), Basic - Definition page.

2. Select the Polarization sub-tab.

3. Select Use.

4. Keep the default setting of Linear.

5. Click Apply .

Add the Radar Receiver's System Noise Temperature

Next, let's add the receiver's system noise temperature to your analysis. You will compute system noise temperature using the default values, and take into account Sun and Cosmic Background noise.

1. Select the System Noise Temperature sub-tab.

2. Select Compute.

3. Select Compute in the Antenna Noise section.

4. Select Sun.

5. Select Cosmic Background.

6. Click **OK** .

7. Save ( ) your scenario.

Probability of Detection

You will base the probability of detection (Pdet) on a value of 0.800000 or higher, one (1) being the highest value. You will also look at signal-to-noise ratio (SNR) and pulse integration. You will start by determining the Pdet of the large turboprop aircraft. Then, you will change Target_Acft's ( ) constant RCS value to simulate a medium sized aircraft, then a small aircraft, and then a bird. Finally, you'll load a notional Aspect Dependent RCS file to see the difference between that and the constant value RCS sphere.

Compute Access

Compute Access ( ) between ASR ( ) and Target_Acft ( ).

1. Right-click on ASR ( ) in the Object Browser.
2. Select Access... ( ).
3. Select Target_Acft ( ) in the Access Tool's associated objects list.
4. Click **Compute** .

Generate a Radar SearchTrack Report

Now that you calculated Access between ASR ( ) and Target_Acft ( ), generate a Radar SearchTrack report.

1. Return to the Access Tool.
2. Click **Report & Graph Manager...** under the Reports section.

3. Expand (⊞) the Installed Styles list if necessary when the Report & Graph Manager opens.

4. Select Radar SearchTrack report ( ).

5. Click **Generate...** .

6. Click **Show Step Value** .Show Step Value At the top of the report.

7. Change the Step: value to 30 sec.

8. Press Enter on the keyboard or click Refresh ( ) at the top of the report.

Understanding the Data

The content of a report or graph is generated from the selected **data providers** for the report or graph style. The data provider you'll focus on in this analysis is ***Radar* SearchTrack**.

Observe Pdet

Look at the difference between S/T Pdet1 and S/T Integrated Pdet in the report. S/T Pdet1 is based off of a single pulse. S/T Integrated PDet uses multiple pulses.

1. Look at the first line in the report.

2. Locate the two columns S/T Pdet1 and S/T Integrated Pdet.

3. Note the difference in the values.

   Pulse integration improves the ability of the radar to detect targets by combining the returns from multiple pulses. You can see this in the S/T Pulses Integrated column in the report.

4. Notice that overall tracking is good when using pulse integration (Pdet of 0.8 or higher).

5. Keep the report open.

Observe SNR

Look at the difference between S/T SNR1 (dB) and S/T Integrated SNR (dB) in the report. S/T SNR1 (dB) is based on a single pulse and S/T Integrated SNR (dB) on pulse integration.

1. Locate the two columns S/T SNR1 (dB) and S/T Integrated SNR (dB).
2. Note the differences in the values.
3. Again, the pulse integration allows for a better SNR.

Observe S/T Ambig Tgt Range

Look at the report to determine if distance from the radar has an effect on the data.

1. Click Report Units ( ) in the Radar SearchTrack report's toolbar.
2. Select Distance Dimension in the Units: Radar SearchTrack window.
3. Select Statute Miles (mi) in the New Unit Value list.
4. Click **OK** to close the Units: Radar SearchTrack window.
5. Scroll over to the right in the Radar SearchTrack report.
6. Locate the S/T Ambig Tgt Range (mi) column. This column tells you how far the aircraft is from the radar site.
7. You see improvement in values discussed above when the aircraft is closer to the radar site.
8. Keep the report open.

Medium Sized Aircraft

Next, simulate a medium sized aircraft.

1. Open Target_Acft's ( ) properties ( ).
2. Select the RF - Radar Cross Section page.
3. Change the Constant RCS Value: to 10 dBsm.
4. Click **Apply** .
5. Return to the Radar SearchTrack report.
6. Click Refresh ( ) at the top of the report.
7. Note the S/T Pdet1, S/T Integrated Pdet, S/T SNR1 (dB), and S/T Integrated SNR (dB) changes.

   The radar's ability to track this aircraft has diminished due to the aircraft's smaller RCS.

Small Sized Aircraft

Simulate a small sized aircraft.

1. Return to Target_Acft's ( ) properties ( )..
2. Change the Constant RCS Value: to 0 dBsm.
3. Click **Apply** .
4. Return to the Radar SearchTrack report.
5. Click Refresh ( ) at the top of the report.
6. Note the S/T Pdet1, S/T Integrated Pdet, S/T SNR1 (dB), and S/T Integrated SNR (dB) changes.

   The radar's ability to track this aircraft has again diminished due to the aircraft's smaller RCS.

Birds and Stealth

Simulate a bird and a large, somewhat stealthy aircraft.

1. Return to Target_Acft's ( ) properties ( ).
2. Change the Constant RCS Value: to -20 dBsm.
3. Click **Apply** .
4. Return to the Radar SearchTrack report.
5. Click Refresh ( ) at the top of the report.
6. Note the S/T Pdet1, S/T Integrated Pdet, S/T SNR1 (dB), and S/T Integrated SNR (dB) changes.
7. Looking at the results, you can only track birds within 10 miles of the airfield.

Aspect Dependent RCS Files

If you have an aspect dependent RCS file built for a specific target aircraft, your data will be much more realistic.

Load External File

Load an installed Aspect Dependent RCS file.

1. Return to Target_Acft's ( ) properties ( ).
2. Change Compute Type: to External File.
3. Click the ellipsis button ( ) beside the Filename field.
4. Browse to <STK install folder>\Data\Resources\stktraining\samples\SeaRangeResources\X-47B

5. Select X-47B_Notional_Sample.rcs.

6. Click **Open** .

7. Click **Reload** .

8. Click **OK** .

Visualize RCS Pattern

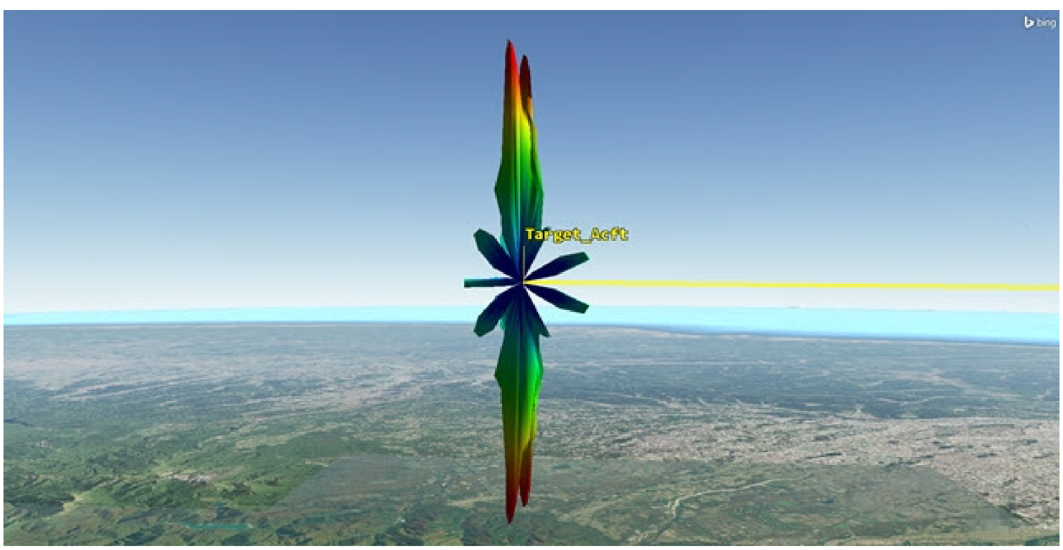
View the RCS pattern in the 3D Graphics window.

1. Bring the 3D Graphics window to the front.

2. Right-click on Target_Acft's () in the Object Browser.

3. Select Zoom To.

4. Use your mouse to get a good view of the aspect dependent RCS pattern.



Aspect Dependent RCS Pattern

View Data

Refresh the Radar SearchTrack report to see the changes in SNR, PDet and Pulse Integration.

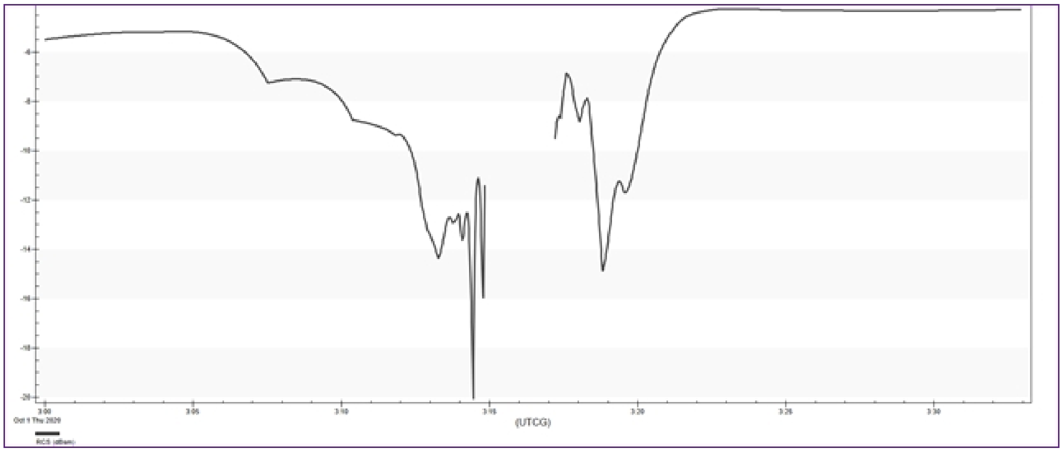
1. Return to the Radar SearchTrack report.
2. Click Refresh ( ) at the top of the report.
3. Note the S/T Pdet1, S/T Integrated Pdet, S/T SNR1 (dB), and S/T Integrated SNR (dB) changes.

   Depending on the reflection from the aircraft back to the radar, you could see fluctuation in your values. This is noticeable in the S/T Pulses Integrated column.

View RCS Data

Use the RCS graph style to visualize changes to RCS Decibel (dBsm). Note the cone of silence in the middle of the graph.

1. Return to the Report & Graph Manager.
2. Ensure the Object Type: is set to Access.
3. Select Place-Radar_Site-Sensor-Servo_System-Radar-ASR-To-Aircraft-Target_Acft in the Object Type: list.
4. Select Radar RCS graph ( ) in the Installed Styles folder.
5. Click **Generate...** .
6. Click **Show Step Value** .Show Step Value At the top of the graph.
7. Change the Step: value to 1 sec.
8. Press Enter on the keyboard or click Refresh ( ) at the top of the report.



Radar RCS Graph

9. Save ( ) your scenario.

Summary

You created a scenario that used the surface of the WGS84 as the central body obstruction. You created a simple flight route of an aircraft and changed its RCS value to simulate a large, four engined turboprop using a constant analytical RCS value. You created an airfield radar site and inserted a Sensor to create a servo system that was used to steer a radar antenna pattern inside its field of view in order to analyze various targets. You built a Radar using specifications typically found on air surveillance radars. You analyzed Pdet values for large, medium, small, and very small targets focusing on Pdet, SNR, and Pulse Integration. Finally, you used a notional aspect dependent RCS file that demonstrated both analytical and visual differences when compared to a constant RCS sphere.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information of various tools and functions. Now is a good time to go back through this tutorial and view that information. Here are a few things you can do:

- Move the radar site to an area that is using a local analytical terrain file and constrain your objects to use terrain for analysis.
- Go on the Internet to find RCS values for other target types and analyze their Pdet values.
- Change settings in the Radar's properties and see their effects on your analysis.

Have fun!

Part 13: Integrating STK with MATLAB

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- STK Integration

Integrating STK and MATLAB

STK's *Integration* capability enables you to control STK from an external application, such as MATLAB. There are several options for how to integrate STK and MATLAB, although the most common method is using Microsoft COM. Using the COM interface, you can connect to STK's Object model and Connect interfaces.

Ansys Techs Say: You can easily explore the Object Model using the .get and .invoke commands from the MATLAB prompt. Additionally, there are code snippets in the STK Help for the STK Object Model.

Did You Know? There are several MATLAB code samples installed with STK. They are in C:\Program Files\AGI\STK 12\CodeSamples\Automation.

Ansys Techs Say: The STK Programming Interface Help has many object-specific MATLAB code snippets to assist you. In the Help menu, select Programming Interface Help and go to Using Core Libraries > STK Object Model > MATLAB Code Snippets.

Ansys Techs Say: A recorded PowerPoint presentation (https://p.widencdn.net/ysl41m/Part16_Integration_JB) and MATLAB script (STK Install Folder\Data\Resources\stktraining\scripts) accompanies this lesson. It is recommended that you follow the presentation while performing the tasks. If you don't want to use the MATLAB Script, you can type the commands right in the MATLAB Command Window.

TASK: CREATE A NEW INSTANCE OF STK FROM INSIDE MATLAB

Let's use MATLAB to create a new instance of STK.

1. Launch MATLAB.
2. Select the Home tab.
3. Click the Open button.
4. Browse to the location of the saved script file.
5. Open the STK_MATLAB_Script.m file (Typically in, <STK Install Folder>\Data\Resources\stktraining\scripts).

MATLAB is up and running. You can use the MATLAB script file to build a simple STK scenario from which you will extract data into MATLAB.

When connected to STK via MATLAB, while creating your variable, using the Tab key after periods enables Intellisense, which displays all of the options available off of the current object. Try it. Create a new instance of STK12 in MATLAB.

1. In MATLAB, type the following code into the Command window:

```
app = actxserver('STK12.application')

app.UserControl = 1

app.Visible = 1
```

Note: To suppress the output message you can add a semicolon (;) at the end of each line.

2. Grab a handle on the STK application root.

```
root = app.Personality2
```

TASK: CREATE A NEW STK SCENARIO FROM INSIDE MATLAB

Now that you have launched STK via the MATLAB interface, let's see if we can create a new scenario, set the time period via MATLAB, and reset the animation time.

1. In MATLAB, place your cursor to the left of the percentage sign for Task 2.
2. Select CTRL + Enter to run all of the MATLAB code in Task 2.

```
%Task 2
```

3. Create a new scenario:

```
scenario = root.Children.New('eScenario','Matlab_Starter')
```

4. Set the analytical time period:

```
scenario.SetTimePeriod('Today','+24hr')
```

5. Reset the Animation Time:

```
root.ExecuteCommand('Animate * Reset')
```

6. Click on your STK scenario and see the name of the scenario, scenario analysis period, and the animation time have been updated.

TASK: INSERT AND CONFIGURE OBJECTS

With a new scenario created, it's time to populate the scenario with objects. Take a moment to create a target and a LEO satellite using MATLAB.

1. In MATLAB, place your cursor to the left of the percentage sign for Task 3.

2. Select CTRL + Enter to run all of the MATLAB code in Task 3.

```
%%
%Task 3
```

3. Add a target object to the scenario.

```
target = scenario.Children.New('eTarget','GroundTarget');
```

4. Move the Target object to a desired location.

```
target.Position.AssignGeodetic(50,-100,0)
```

5. Add a satellite and configure its properties.

```
satellite = scenario.Children.New('eSatellite','LeoSat')
```

6. Propagate the satellite object's orbit.

```
root.ExecuteCommand(['SetState */Satellite/LeoSat Classical TwoBody
"',scenario.StartTime,'" "',scenario.StopTime,'" 60 ICRF
"',scenario.StartTime,'" 7200000.0 0.0 90 0.0 0.0 0.0'])
```

7. Click on the STK scenario and look at the added Ground Target at)50, -100) and the Propagated LeoSat.

TASK: COMPUTE ACCESS BETWEEN OBJECTS

You have a scenario with a target object and a satellite object. You can determine when the satellite object can access the target object.

1. Browse to STK's Programming Interface Help files.

2. Locate and manually enter code into MATLAB to compute an access between two STK Objects using the IAgStkObject interface. The access is between the satellite object and the target object.

a. The location of the required code snippets is STK Programming Interface -> Using Core Libraries -> STK Object Model -> MATLAB Code Snippets.

b. Locate the Compute an access between two STK Objects (using IAgStkObject interface) page.

c. Type the following code

```
access = satellite.GetAccessToObject(target)
access.ComputeAccess
```

d. Bring the STK scenario to the front and look for the access ground tracks in the 2D Graphics window.

3. Retrieve access interval start/stop times.

4. In MATLAB, place your cursor to the left of the percentage sign for Task 4.

5. Select CTRL + Enter to run all of the MATLAB code in Task 4.

```
accessDP = access.DataProviders.Item('Access Data').Exec
(scenario.StartTime,scenario.StopTime);
 accessStartTimes = accessDP.DataSets.GetDataSetByName('Start Time').GetValues
 accessStopTimes = accessDP.DataSets.GetDataSetByName('Stop Time').GetValues
```

6. Scroll through the MATLAB Command Window to see the access start and stop times.

Note: Generating the Start & Stop times in MATLAB can also be done using the following lines of code.

```
accessIntervals = access.ComputedAccessIntervalTimes

accessDataProvider = access.DataProviders.Item('Access Data')

for i = 1:1:accessIntervals.Count
        [start, stop]   = accessIntervals.GetInterval(i-1)
end
```

More information available in STK Object Model Tutorial.

TASK: RETRIEVE SATELLITE ALTITUDE DURING ACCESS

1. Retrieve and view the altitude of the satellite during an access interval.

2. In MATLAB, place your cursor to the left of the percentage sign for Task 5.

3. Select CTRL + Enter to run all of the MATLAB code in Task 5.

```
%%
%Task 5

satelliteDP = satellite.DataProviders.Item('LLA State').Group.Item
('Fixed').ExecElements(accessStartTimes{1},accessStopTimes{1},60,
{'Time';'Alt'});
 satellitealtitude = satelliteDP.DataSets.GetDataSetByName('Alt').GetValues
```

4. Scroll through the MATLAB Command Window to see the altitude data output.

Ansys Techs Say: After the analysis, enter the following code in the Command window to save the scenario. First create a folder where you would like to save the scenario.

```
% Enter the file path of where you would like to save the materials
filePath = ['Your File Path' scenario.InstanceName]
%Create a new scenario folder in that location
mkdir(filePath);
%save the scenario
root.SaveScenarioAs([filePath '\MatlabStarter.sc']);
```

After you save, you can also close out of your scenario:

```
root.CloseScenario();
```

Important: Don't forget to save your work!

Note: For additional MATLAB training with STK, refer to: Using MATLAB for STK Automation (PDF).

Part 13: Integrating STK with Python

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: This lesson requires STK 12.2 or newer to complete it in its entirety. It includes new features introduced in STK 12.2. If you have STK 12.1 or earlier, you can find that lesson **here**.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro
- STK Integration

Problem statement

You will be analyzing the behavior of a satellite when it has contact with a ground site. The task will be repetitive and you consider methods of automating the process and extracting the data. Knowing that you can integrate STK with other tools you decide to explore the process.

Solution

Analysis in STK can be integrated and automated with code. You decide to run the process with Python. Using the resources on the STK Help and Github, you explore how to model a mission with a script.

From this tutorial you will learn how to:

- Connect STK to a programming interface
- Build a mission through a script
- Extract data from STK

Ansys Techs Say: A recorded PowerPoint presentation (https://p.widencdn.net/ysl41m/Part16_Integration_JB), Jupyter Notebook, and Python script (<STK Install Folder>\Data\Resources\stktraining\scripts) accompany this lesson. It is recommended that you follow the presentation while performing the tasks. If you don't want to use the shared files, you can type the commands right in the Python Command Window.

Familiarize yourself with the STK Programming Interface Help

Before attempting to code anything, take a moment to familiarize yourself with the STK Programming Interface Help system. After going through the Help, you will dive into Integrating STK and Python. This example is done with the built-in user interface, which was introduced in STK 12.2. However, you can view the archived lesson using Jupyter Notebook and Python here.

Historically, integrating STK Desktop and STK Engine was achieved with either win32com or through the comtypes Python module. In STK 12.1, a new STK Python API was developed to provide the following:

- Cross-platform support: Code written using the new API interacting with STK Engine can be used on Windows and on Linux without modifications (assuming the usual cross platform Python guidelines are followed).
- Usability improvements:
  - The new API provides definitions for all enumerations. With win32com, enumerations had to be defined manually based on the corresponding numerical value.
  - Better IDE support through type hints (based on the typing module).

For STK 12.2 and newer, you can use Jupyter notebooks directly inside STK with the Python User Interface. This enables you to use Python scripting language to:

- Automate STK from Windows or Linux platforms
- Streamline your workflow

- Provide a more interactive development experience

The Python API has also been expanded to support STK events and to expose the globe and map controls, enablng you to develop custom applications in Python.

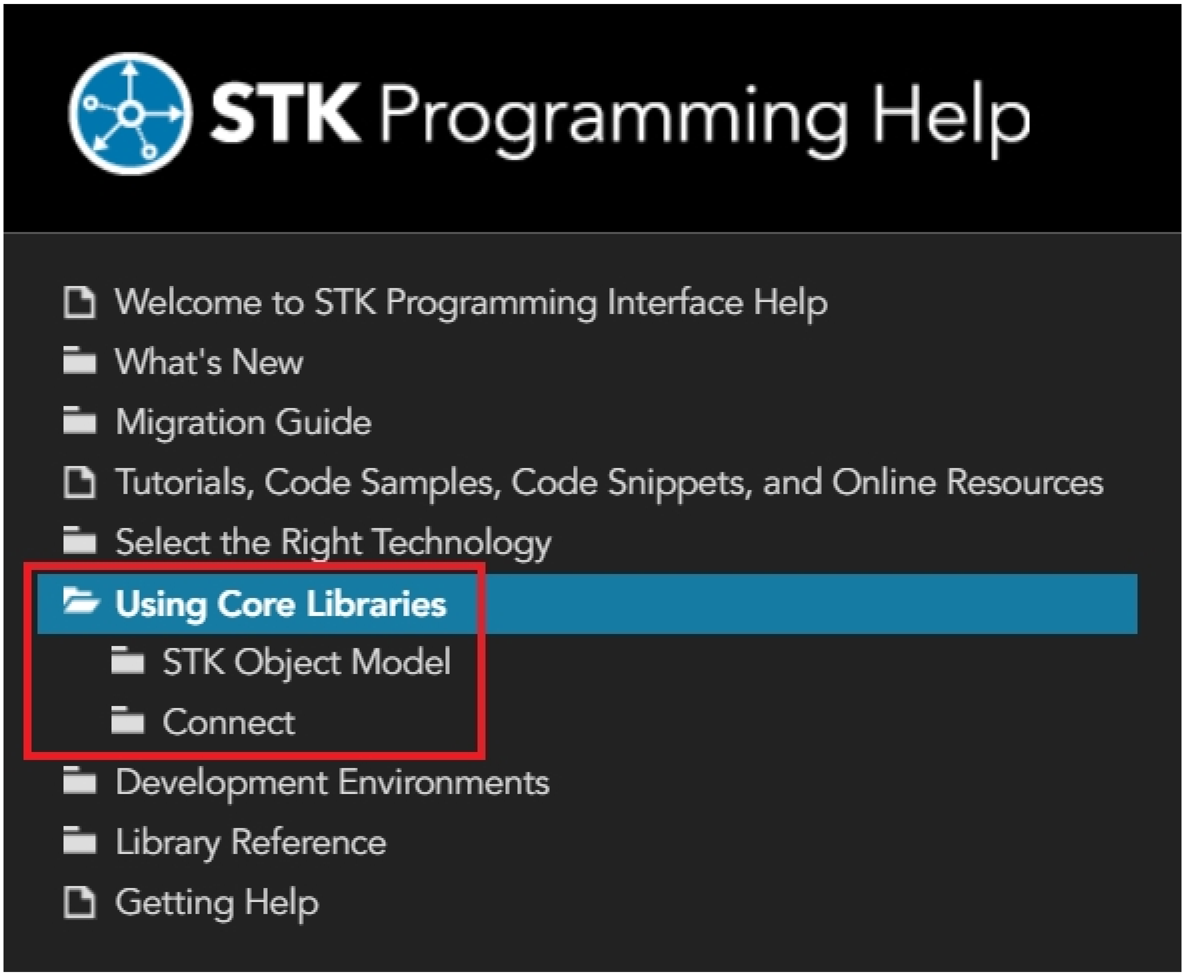
Resources for Integrating STK are available both online and locally if installed with the STK installation. You can access these in several different ways:

- Go directly to the online STK Programming Help page: **help.agi.com/stkdevkit/.**
- Launch STK Programming Help from within STK. Click Help on the menu bar and select Programing Interface Help.
- Launch the STK Help via the windows Start Menu: Select Start → STK 12 → STK 12 - Programming Interface Help.

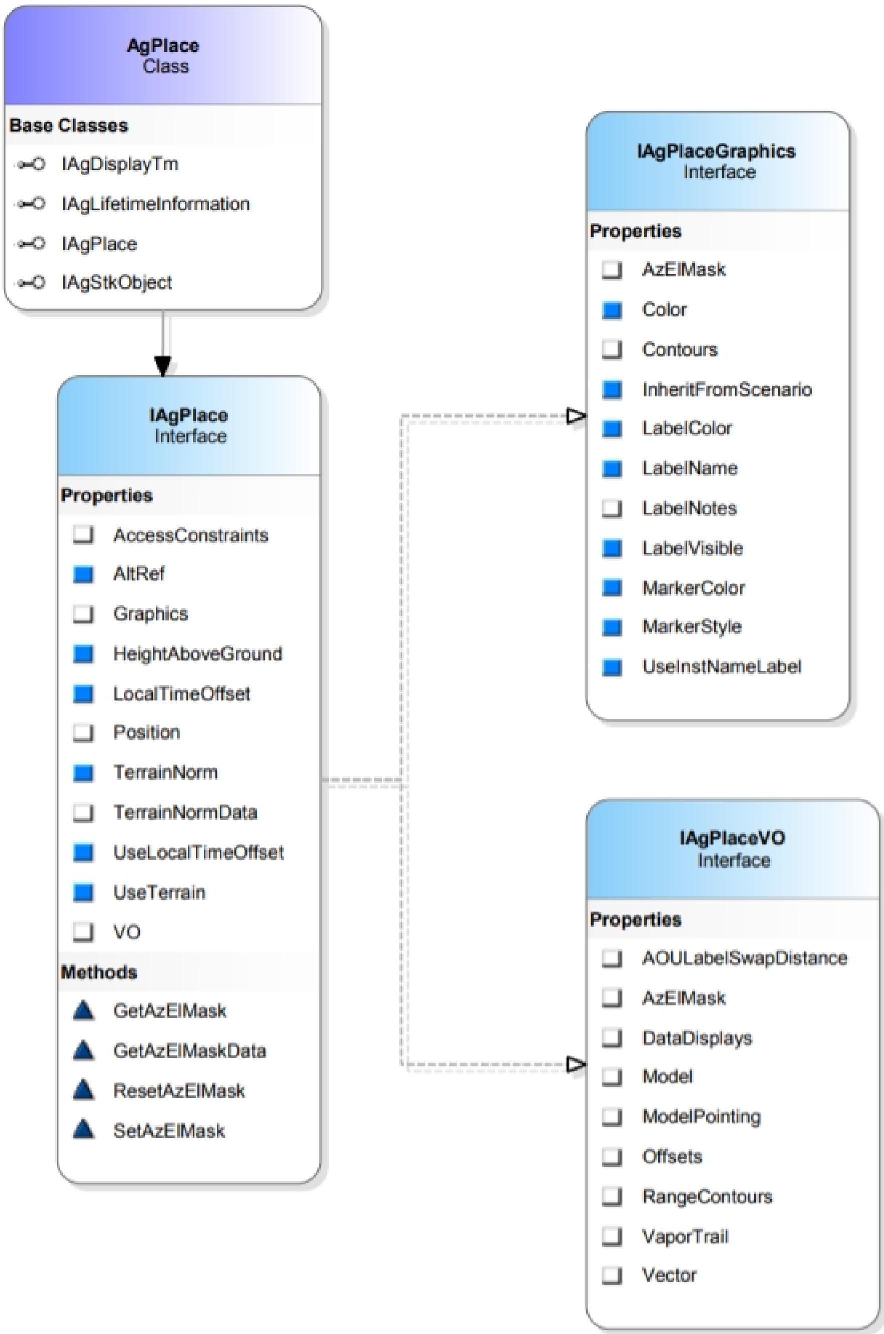
You will find a wealth of information within the STK Programing Interface Help system, including integration tutorials, code snippets, decision trees, and library references.

The help system tree looks like this:

Within the Using Core Libraries directory, you will find additional information on using the STK Object Model and Connect.



The STK Object Model section listed under Using Core Libraries contains useful code snippets in various programming languages. It also contains information on the various COM libraries that make up the STK Object Model. This information includes useful diagrams that help visualize how the STK Object Model is structured. For example, this small excerpt from the STK Object diagrams which outlines a portion of the basic STK Object Model representation of a Place object:



In the using Core Libraries - Connect section, you will find useful Getting Started information outlining the basics of Connect command and response formats. The section also contains useful code snippets that demonstrate the syntax for various Connect commands. Here is an example of a code snippet showing how to create a new missile object:

Create New Missile

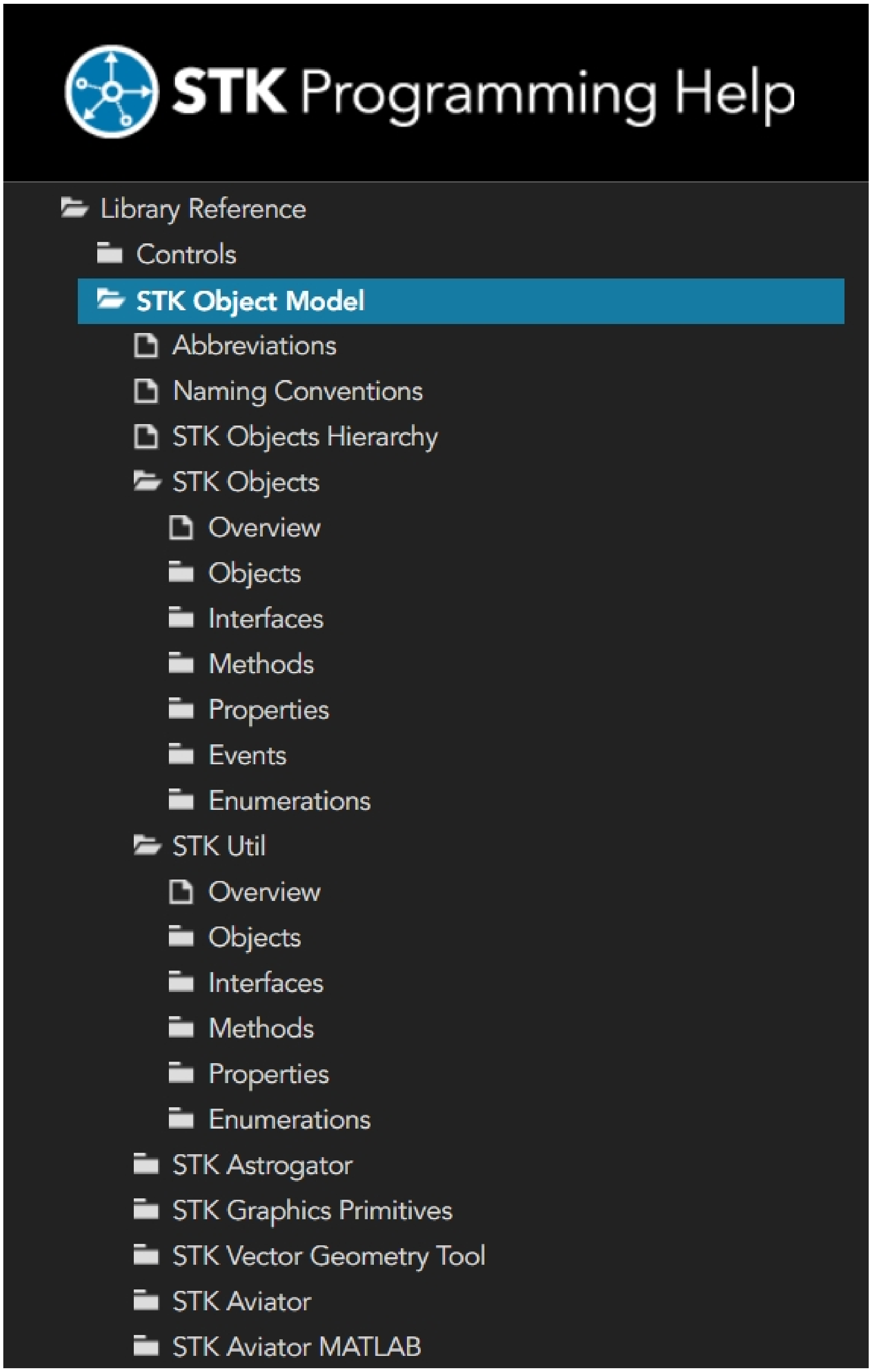
[Connect]

```
root.ExecuteCommand('New / */Missile MyMissile');
```

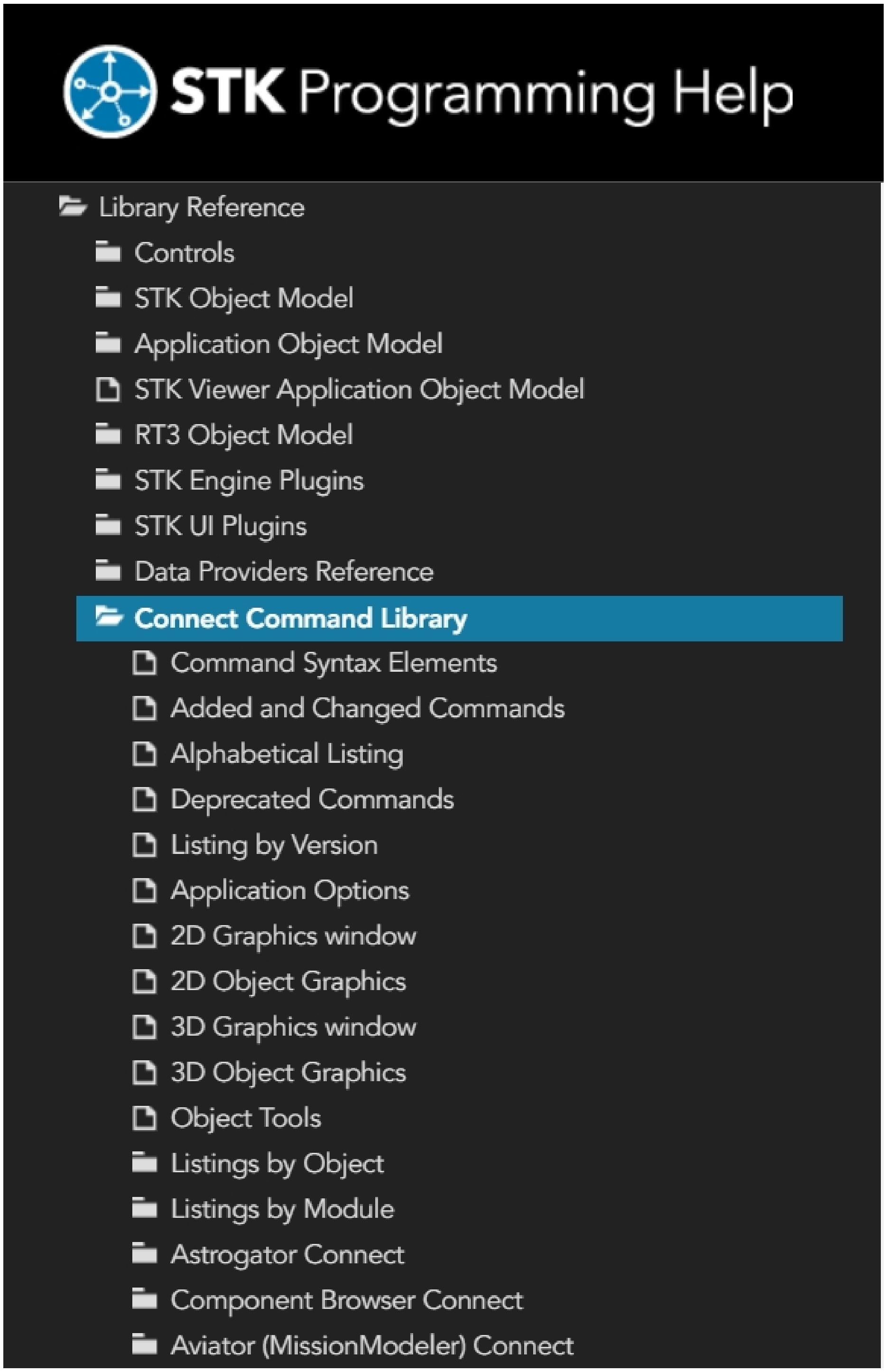
Note: This snippet utilizes STK Object Model to send the Connect command. The raw Connect command is the string being passed to root.ExecuteCommand().

You can and should explore more of the help sections, but one last important section to point out is the Library Reference section.

Under Library Reference, you will find documentation on the STK Object Model, Connect Command Library, Data Providers, and more. The STK Object Model documentation is organized by the individual libraries, so there is a section for STK Objects, a section for STK Util, and so on with each section encapsulating certain aspects of functionality. Within each section items are broken down further by their type. When needed, this can make it quicker to find the exact item you are looking for.



The Connect Command Library, listed under Library Reference, houses the documentation for all of the Connect commands. In this case commands are listed in several different formats, including alphabetically, by object, and by capability to assist in locating the exact reference needed.



Try it

To find help for the AgStkObjectRoot class:

1. Click Library Reference → STK Object Model → STK Objects.
2. Scroll down the alphabetical list until you find the entry entitled "AgStkObjectRoot".
3. Click AgStkObjectRoot to display detailed information and important links, including a link to the IAgStkObjectRoot interface.
4. From there, you can access a listing of all the members (methods and properties) of the interface associated with the AgStkObjectRoot object. Similarly, you can find help for any other object or interface, as well as any method, property, or enumeration.

A quick way to find help on a given type is to use the Search tab of the Help system. For example, suppose you are interested in the AgECoordinateSystem enum. If you enter "AgECoordinateSystem" in the search field and click List Topics, a list of pages containing that term appears. The entry for the AgECoordinateSystem reference page will appear at the top. Select that entry to display a page defining the enum and listing its members.

A final note on the STK Programming Interface Help system

In addition to help on programming issues, the help provides information about the real-world context in which the application is to be used. For example, the STK Object Model help page for the SpinAxisConeAngle property tells you that it is writable, is of the Variant data type, and belongs to the IAgSnPtSpinning interface. In addition, it tells you that the property represents "the cone angle used in defining the spin axis; i.e., the angle between the spin axis and the sensor boresight." This latter information is useful in deciding whether or not and how to use the property in your application, but since the help is mainly intended to provide guidance on programming issues it is best to also reference the STK Help System, where there is generally more information. For example, the help page for “Spinning Sensor Pointing” not only gives more detailed context information but also includes a drawing of spin axis geometry that illustrates the spin axis cone angle quite clearly.

Integrating STK and Python

Ansys Techs Say: The STK Programming Interface help has many object-specific **Python code snippets** to assist you. Visit our FAQ site to learn more about Python-STK COM Integration (https://analyticalgraphics.force.com/faqs/articles/Keyword/Getting-Started-STK-COM-integrationsing-Python). Additional Python Resources are on **Github** Github https://github.com/AnalyticalGraphicsInc/STKCodeExamples/tree/master/StkAutomation/Python).

Before you start: Integrating STK with Python

This lesson was written with Python 3.7.7, but you can use other versions of Python. See the FAQ article at https://analyticalgraphics.force.com/faqs/articles/HowTo/Troubleshooting-your-STK-and-Python-integration for details on compatible versions. Before starting this lesson, verify that you have a working Python environment. This example uses the built-in Jupyter Notebooks. You may also use your preferred Python environment (i.e., WinPython, Spyder, Anaconda, or others).

TASK: CREATING AN STK SCENARIO

There are several ways to open Jupyter Notebooks. You will try opening it inside STK. You may download the script linked above or follow below. First, create an STK scenario.

1. Create a new STK scenario.
2. Click **Create a Scenario** .
3. Enter the following in the New Scenario Wizard:

Option	Value
Name	STK_Python_Training
Start Time	Default Start Time
Stop Time	Default Stop Time

4. Click **OK** .

TASK: INTEGRATING STK AND PYTHON

Launch the Python Scripting Interface.

1. Click View on the STK menu bar.
2. Select Toolbars.
3. Select Integrated Jupyter Notebooks for Python.
4. Examine the three buttons. The first button from the left opens the interface, the second opens the Github, and the final one opens the Programming Help.
5. Click Launch Python Scripting Interface ( ).
6. If not specified, click the ellipsis button ( ) in the Python Interpreter Path field to set the Python install path.
7. If not specified, click the ellipsis button ( ) in the **Path to script or folder field** to set the folder location where you would like to save your script. By default it will be saved to your C:<user path>\Documents\STK 12\PythonScripts.
8. Clear the Create new script on open check box. In this lesson, you will use a notebook file available in your install or from download.

   > **Note:** You can create a new script on open by selecting the **Create new script on open** check box.

9. Click Launch.
10. Either Download or browse to the installed Python_Jupyter_STK_Training.ipynb file located at STK Install Folder\Data\Resources\stktraining\scripts.
11. Save the file to the path specified in the **Path to script or folder** option above.

TASK: SETTING UP YOUR WORKSPACE

You will be using Jupyter notebooks. You will add cells and enter our script into sections and run them. You may also use the completed script by adding or writing in any missing lines of code. If you are building your script from scratch, use the following commands and paste them into the notebook cell:

1. Set up your workspace.

> **Note:** The new STK Python API is only available with STK 12.1 or newer. If not installed, use pip to install it. Example code: **pip install "C:\Program Files\AGI\STK 12\bin\AgPythonAPI\agi.stk<..ver..>-py3-none-any.whl"** . If using an older version of STK, then use win32com or comtypes.

```
# STK library imports

from agi.stk12.stkdesktop import STKDesktop

from agi.stk12.stkobjects import *

from agi.stk12.stkutil import *

from agi.stk12.vgt import *

# if using astrogator uncomment the below

# from agi.stk12.stkobjects.astrogator

# if using aviator uncomment the below

# from agi.stk12.stkobjects.aviator

# Python helper library imports

import os
```

2. Connect to the STK instance. Use the appropriate scrip below depending on how you connect to STK.

   Use STK_PID environment variable when using the Jupiter Notebook plugin and have multiple instances of STK running.

```
STK_PID = os.getenv('STK_PID')
```

```
stk = STKDesktop.AttachToApplication(pid=int(STK_PID))
```

Use STKDesktop.AttachToApplication() without reference to STK_PID when running a single instance of STK. It does not matter if you are in a notebook or not.

```
stk = STKDesktop.AttachToApplication()
```

3. Grab a handle on the STK application root.

   Recall that the AgStkObjectRoot object is at the apex of the STK Object Model. The associated IAgStkObjectRoot interface will provide the methods and properties to load or create new scenarios and access the Object Model Unit preferences. Through the stk command you have a pointer to the IAgUiApplication interface; however, the STK Python API provides a direct handle to the IAgStkObjectRoot via the Root property in STKDesktop or the NewObjectRoot() method in STKEngine.

```
root = stk.Root
```

4. Check that the root object has been built correctly and check the type(). The output will be agi.stk.stkobjects.AgStkObjectRoot.

```
type(root)
```

5. Once the above lines are entered into the cell, click **Run** . This will create a new STK window.

TASK: CONNECT AND DESIGN A NEW SCENARIO

Now that you have launched STK via the Python interface, see if you can create a new scenario and set the time period via Python. Create a new scenario and analysis period and reset the animation time.

1. Click **insert cell below** to add a new cell.
2. Copy the following code to create a new scenario.

```
# 1. Define a scenario object.
```

```
scenario = root.CurrentScenario
```

3. Copy the following code to set the analysis period.

```
# 2. Set the analytical time period.
```

```


  scenario.SetTimePeriod('Today','+24hr')
```

4. Copy the following code to reset the animation time.

```
# 3. Reset the animation time to the newly established start time.
```

```
root.Rewind();
```

5. Click Run .

TASK: INSERT AND CONFIGURE OBJECTS

With a new scenario created, it's time to populate the scenario with objects. Use the STK Python API and the STK Connect commands, via the ExecuteCommand method, to create a facility and a LEO satellite.

1. Click insert cell below to add a new cell.

2. Copy the following code to add a target object to the scenario. Casting the object returned from the New () method allows for better intellisense in your IDE but is optional; the object returned will be AgTarget at runtime even without the case.

```
# 1. Add a target object to the scenario.
```

```
target = AgTarget(scenario.Children.New
(AgESTKObjectType.eTarget,"GroundTarget"))
```

3. Copy the following code to move the target object to the desired location.

```
#2. Move the Target object to a desired location.
```

```
target.Position.AssignGeodetic(50,-100,0)
```

4. Copy the following code to add a satellite object to the scenario.

```
#3. Add a Satellite object to the scenario.
```

```
satellite = AgSatellite(root.CurrentScenario.Children.New
(AgESTKObjectType.eSatellite,"LeoSat"))
```

```
#Examine the below connect command before running. In it we will be
using the Set State Classical connect command. Rather than manually
setting the times we will use the define scenario times. Print them to
confirm.
```

```
print(scenario.StartTime)
```

```
print(scenario.StopTime)
```

5. Copy the following code to propagate the satellite object for the length of the scenario.

```
#4. Propagate the Satellite object's orbit.
```

```
root.ExecuteCommand('SetState */Satellite/LeoSat Classical TwoBody "'
+ str(scenario.StartTime) + '" "' + str(scenario.StopTime) + '" 60
ICRF "' + str(scenario.StartTime) + '" 7200000.0 0.0 90 0.0 0.0 0.0');
```

6. Click Run .

TASK: COMPUTE ACCESS BETWEEN OBJECTS

You now have a scenario with a Target object and a Satellite object. Determine when the Satellite object can access the Target object.

1. Go to the STK Programming Interface Help files.
2. Locate the code needed to compute an access between two STK Objects using the IAgStkObject interface. The access is between the Satellite object and the Target object.
3. If you cannot locate the code, expand the following
    a. The location of the required code snippets is STK Programming Interface > Using Core Libraries > STK Object Model > Python Code Snippets. Locate STK Objects > Access. The required snippet is Compute an access between two STK Objects (using IAgStkObject interface).

    ```
    access = satellite.GetAccessToObject(target)
    ```

    ```
    access.ComputeAccess();
    ```

4. In the JupyterNotebook, click insert cell below to add a new cell.
5. Enter the above text to the new cell and click Run .

TASK: RETRIEVE ACCESS DATA FROM STK

Now that the scenario is fully built, the final task is to extract data and perform a basic analysis. You have just computed access between the two objects, so you can use the STK data providers to pull data out of the scenario.

1. Click insert cell below to add a new cell.
2. Copy the following code to add calls to the access data provider. This will retrieve and view the access data in Python.

```
accessDP = access.DataProviders.Item('Access Data')
```

```
results = accessDP.Exec(scenario.StartTime, scenario.StopTime)
```

```
accessStartTimes = results.DataSets.GetDataSetByName('Start
Time').GetValues()
```

```
accessStopTimes = results.DataSets.GetDataSetByName('Stop
Time').GetValues()
```

```
print(accessStartTimes,accessStopTimes)
```

3. Click Run .

Note: You can also pull the Start & Stop times in Python using the following lines of code.

```
accessIntervals = access.ComputedAccessIntervalTimes

dataProviderElements = ['Start Time', 'Stop Time']

for i in range(0,accessIntervals.Count):
        times = accessIntervals.GetInterval(i)
        print(times)
```

More information is available in STK Object Model Tutorial.

TASK: RETRIEVE THE SATELLITE ALTITUDE DATA FROM STK

1. Click insert cell below to add a new cell.

2. Copy the following code to add a call to the satellite's LLA state data provider. Retrieve and view the altitude of the satellite during an access interval. In the following lines, note how the data providers must follow the data provider folder, subfolder, and selection.

```
satelliteDP = satellite.DataProviders.Item('LLA State')
```

```
satelliteDP2 = satelliteDP.Group.Item('Fixed')
```

```
rptElements = ['Time', 'Lat', 'Lon', 'Alt']
```

```
satelliteDPTimeVar = satelliteDP2.ExecElements
(accessStartTimes,accessStopTimes, 60, rptElements)
```

```
satelliteAltitude = satelliteDPTimeVar.DataSets.GetDataSetByName
('Alt').GetValues()
```

```
print(satelliteAltitude)
```

3. Click Run .

TASK: SAVE YOUR SCENARIO

You have just completed the Integrating STK with Python tutorial using Jupyter Notebooks. Don't forget to save your work. With your scenario safely saved, you can close out of STK. You can expand and automate workflows like these for quickly building and analyzing missions.

Part 13: Integrating STK with Excel

Required Product Licenses: STK Pro, STK Premium (Air), STK Premium (Space), or STK Enterprise You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Important: Ensure you are working out of one module at a time. Some users have noted that *Microsoft Excel* will generate additional code modules if you relaunch the *Excel* workbook.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro
- STK Integration

Problem statement

Developers, engineers and operators need to quickly and easily automate repetitive tasks from outside of the STK application, integrate STK with other applications, such as *Microsoft Excel*, *MATLAB*, and *Python*, develop custom applications and leverage the AGI Object Model collection of COM libraries from other applications. You want to be able to create, drive and extract data from a simple STK scenario using *Excel*. You need to understand access to the following Application Programming Interfaces (API): the STK Object Model and Connect. Finally, you require a basic comprehension of STK Programming Help.

Solution

Use *Excel* to create a new instance of STK and expose the object root. Next, build a new scenario, populating it with a Satellite object and multiple Target objects. Create an access between the Satellite object and a selected Target object. Use the data providers, groups, and elements to retrieve access times from STK into *Excel*. Download, install and use the STK Excel Add-in plugin. Learn the power of STK Programming Help.

What you will learn

Upon completion of this tutorial, you will have a basic understand of the following:

- STK Programming Help
- STK Object Model
- *Connect*
- Data Providers
- Sending and Receiving Data Between STK and *Excel*
- STK Excel Add-in

> **Note:** STK and *Excel* should be shut down prior to starting this tutorial. This tutorial is not designed to teach you how to use *Excel*. It's an introduction to integrating *Excel* with STK and pulling data from STK into *Excel*. It's also an introduction to STK Programming Help and how important it is to be able to intelligently browse the help pages.

STK Programming Help

The STK Programming Help offers a wide variety of options to automate and customize STK and to integrate its technology into other applications. Only a small portion of the STK Programming Help is covered in this tutorial but it's a great starting point.

1. Open your preferred Internet browser.
2. Go to help.agi.com.
3. Select STK Programming Help.

STK PROGRAMMING HELP LINK

> **Note:** If you do not have an internet connection, you can find the Programming Help by extending the Help menu inside STK and selecting Programming Interface Help.

Integrating STK with other applications

STK's Integration capability enables you to automate repetitive tasks from outside the STK application, integrate STK with other applications – such as *Excel* and *MATLAB* – develop custom applications, and leverage the AGI Object Model collection of COM libraries from other applications.

1. Choose Select the Right Technology in the contents list on the left side of STK Programming Help.
2. Select Integrate Technologies.
3. Select **clickable decision tree** on the Integrate With Other Applications page.
4. Take a moment to view the page and click some of the icons.

   There are multiple clickable decision trees available in STK Programming Help. You can use the trees to quickly locate help pages that you need to be successful when using integration.

Automating repetitive tasks

To automate repetitive tasks in STK, you can use HTML, Connect, and STK Objects to build tools that are accessible from within STK.

1. Return to STK Programming Help.
2. Choose Select the Right Technology in the contents list.
3. Select Automate Tasks.
4. Select **clickable decision tree** on the Automate Repetitive Tasks page.
5. Take a moment to view the page and click some of the icons.

Extending AGI products

AGI provides a variety of ways to extend our products. These extensibility mechanisms can be divided into two distinct areas: user interface extensibility and engine extensibility.

1. Return to STK Programming Help.
2. Choose Select the Right Technology in the contents list.
3. Select Extend AGI Products.
4. Click **clickable decision tree** on the Extend AGI Products Using Plugins and Custom User Interfaces page.
5. Take a moment to view the page and click some of the icons.

   There are other links throughout that aren't covered here. Take some time later on to become familiar with them.

Visualize

STK X allows developers to add advanced STK 2D, 3D visualization and analytical capabilities to applications with little effort.

1. Return to STK Programming Help.
2. Choose Library Reference in the contents list.
3. Select Controls.
4. Select STK X.
5. Take some time to familiarize yourself with the contents of this page.

Using Core Libraries

The STK API consists of two major sub-systems: Connect and the STK Object Model.

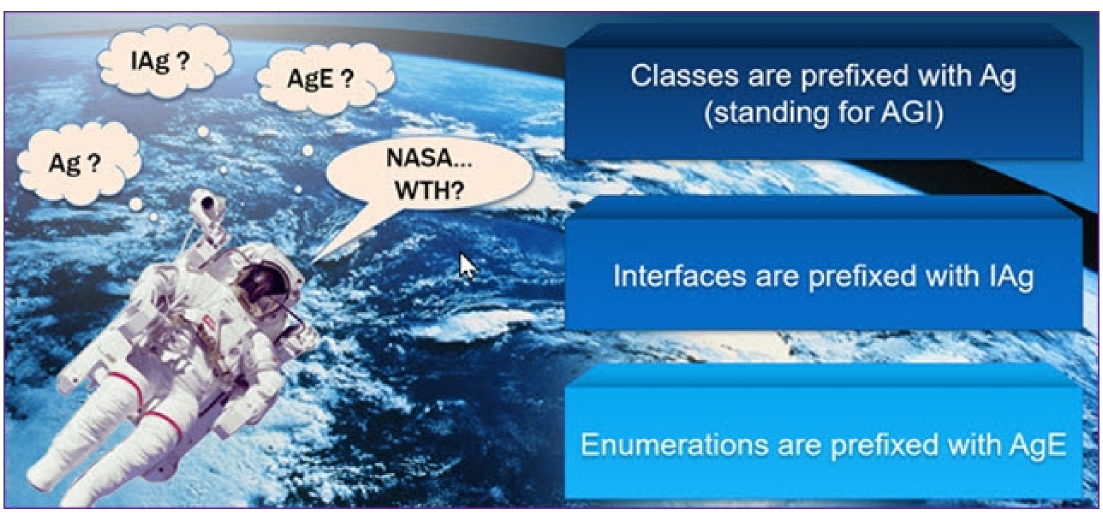
- Connect is a library of string commands for STK, originally designed to operate over a TCP/IP socket.
- The STK Object Model is an object-oriented interface to STK, built on Microsoft COM technology.

1. Return to STK Programming Help.
2. Choose Using Core Libraries in the contents list.
3. Note the advantages and disadvantages of using each library.

   The choice of Connect or Object Model should be driven by the requirements of the application and the needs of the developer. It is important to note, however, that this need not be an exclusive choice. Connect commands can be used in a COM application side-by-side with Object Model Code.

Naming conventions

The STK Object Model contains naming conventions for classes, interfaces and enumerations.



1. Return to STK Programming Help.
2. Choose Library Reference in the contents list.
3. Select STK Object Model.
4. Select Naming Conventions.
5. Note the various naming conventions described on the Naming Conventions Used In the Various Core Libraries page.
6. Select Abbreviations in the contents list.
7. Note the abbreviations most commonly used in the names of classes, interfaces and other types in the STK Object Model.

Model diagrams

For the serious programmer, you can use diagrams to see how the STK traffic flow is connected. That way, you know what's to the right, left, above and below, all while deep-linking to the individual IAg interface pages.

1. Return to STK Programming Help.
2. Choose Using Core Libraries in the contents list.
3. Select STK Object Model.
4. Select STK Objects.
5. Select Diagrams.
6. Select STK Object Model Diagram (PDF) on the STK Objects Object Model Diagrams page.
7. Zoom into the page for clarification if desired.
8. Take some time to look at the STK 10.0 Object Model Diagrams PDF.

9. Close the STK Object Model Diagram (PDF) when finished.

10. Keep STK Programming Help open.

STK Excel Add-in

The STK Excel Add-in is a set of VBA libraries, macros, forms and toolbars that let *Excel* users interact with STK and STK scenarios directly from *Excel*. You can pull data from STK into *Excel* or pass certain data types from *Excel* into STK. The STK Excel add-in may already do what you require. At the end of this tutorial, the STK Excel Add-in tool will be used, so now is a good time to install it on your computer.

1. Go to https://www.agi.com/ in your preferred browser.
2. Click **SIGN IN** at the top of the page.
3. Select Sign In in the shortcut menu.
4. Enter your credentials in the Sign In page.
5. Click **SIGN IN** .

Downloads

1. After signing in, at the top of the page, select Support.
2. Select Downloads once the menu opens.
3. If presented, read the Software License Agreement. Otherwise, go to step 5.
4. Click **ACCEPT** .
5. On the Software Downloads page, locate Data and Auxiliary Extensions.

6. Select STK Excel Add-in (v12.0.0).

   This will download the install file as a zipped folder to your designated download location.

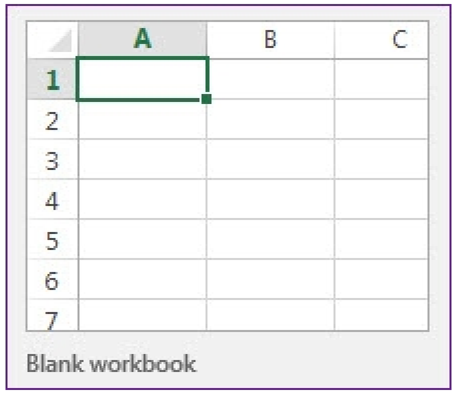
Installing the STK Excel Add-in

1. Go to your download location.
2. Unzip (Extract All) the STKExcelAdd-in_v12.0.0.zip folder to your preferred location.
3. Open the extracted (unzipped) STKExcelAdd-in_v12.0.0 folder.
4. Double-click STKExcelAdd-in_v12.0.0.
5. If you receive a security warning, click **Run** .
6. Run the installer.
7. Keep STK Programming Help open.
8. Close any open folders and web pages that your desire.

Configuring Excel

Enable the Developer tab and the STK Excel Add-in.

1. Launch *Excel*.
2. Click Blank workbook once *Excel* launches.

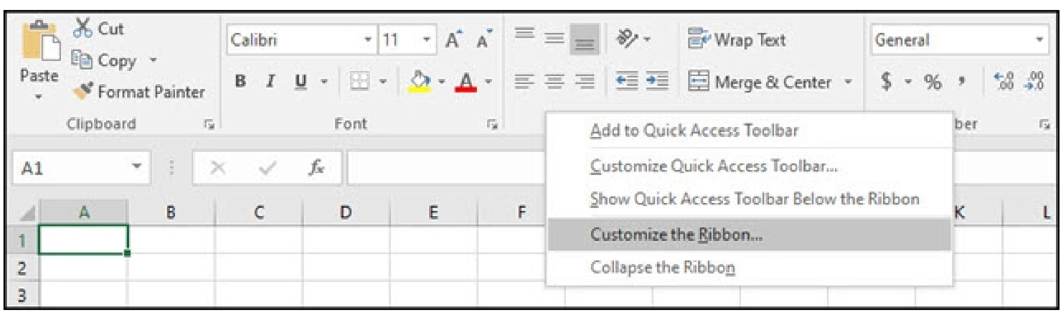


BLANK WORKBOOK

Excel Developer Tab

Turn on the Developer tab in *Excel* if you want to create a macro, export and import XML files or insert controls. If it's not already turned on, complete the following steps.

1. Right-click anywhere on the ribbon.
2. Select Customize the Ribbon...



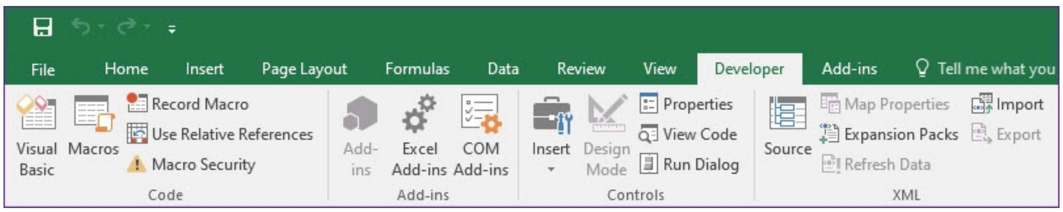
EXCEL RIBBON

3. Select Main tabs (if necessary) under Customize the Ribbon shortcut menu in the *Excel* Options dialog box.
4. Select the Developer check box.

5. Click OK .

Turning on the STK Excel Add-in

1. Select the Developer tab.



DEVELOPER TAB

2. Click Excel Add-ins .
3. Select the Stk Add-in 12 X64 check box in the Add-ins dialog box.
4. Click OK .
5. Close *Excel*. This is required.

Creating an Excel Workbook

Create a workbook and save the file to a custom folder.

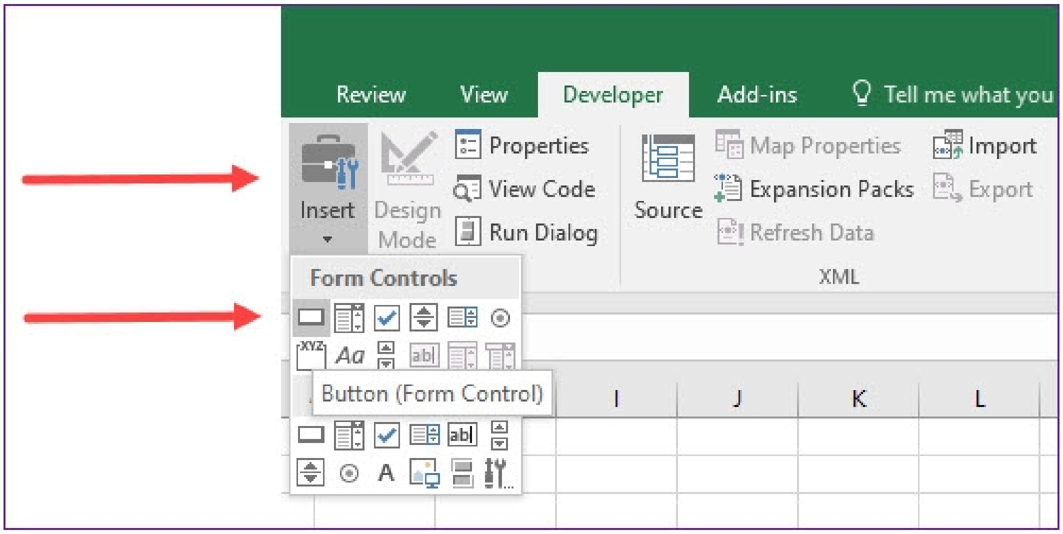
1. Launch *Excel*.
2. Click Blank Workbook.
3. Select the File menu when the workbook opens.
4. Click Save As in the contents list on the left.

5. Select Browse.
6. Select Desktop in the Save As dialog box.
7. Select New folder in the menu bar.
8. Rename New folder to STK_Excel.
9. Click **Open** .
10. Type STK_Excel_Workbook in the File name: field.
11. Open the Save as type: shortcut menu.
12. Select Excel Macro-Enabled Workbook.
13. Click **Save** .

Form Control Button

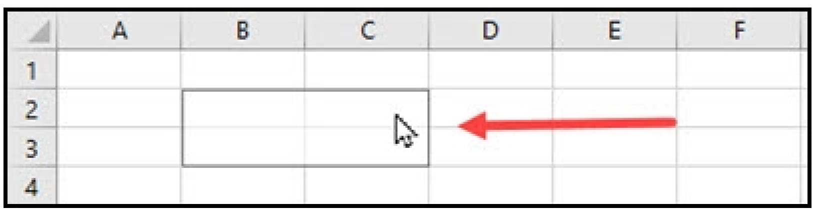
Turn on the Excel Form Control button.

1. Select the Developer tab.
2. Click **Insert** .
3. Click Button (Form Control) in the shortcut menu.



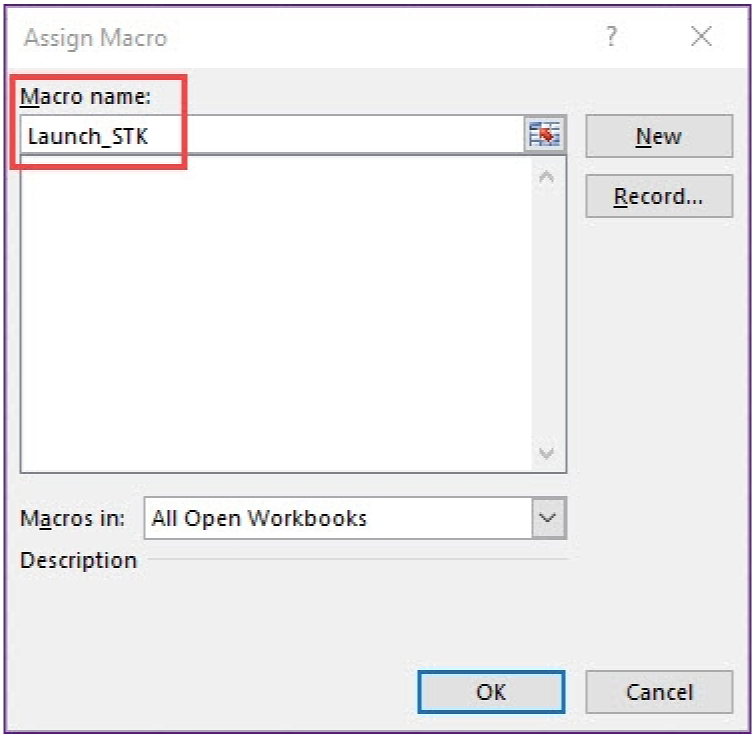
FORM CONTROLS

4. Hold down your left mouse button and draw out a small box in the *Excel* workbook.



SMALL BUTTON BOX

5. Type Launch_STK in the Macro name: field when the Assign Macro tool dialog box opens.



MACRO NAME

6. Click New .

Change the Button's Name

Give the button a unique name.

1. Bring the *Excel* workbook to the front.
2. Highlight the button name (e.g. Button 1) in the button.
3. Type Launch STK.

Creating an STK Instance from Excel

You will use the *Excel* script file to build a simple STK scenario from which you will extract data into *Excel*. You can use VB script or the STK object model and for automation you can use your preferred method. STK Connect will be demonstrated in this tutorial. All the components of Integration are fully documented, and AGI maintains a GitHub repository of Code samples to help you get started with the STK Object Model. There is a learning curve, so start with STK Programming Help.

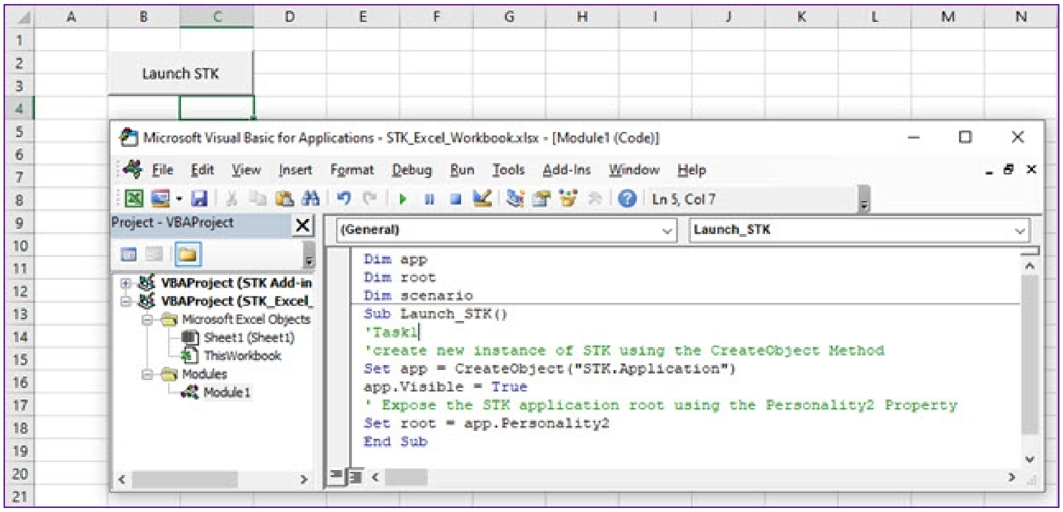
> **Important:** Ensure you are working out of one module at a time. Some users have noted that *Microsoft Excel* will generate additional code modules if you relaunch the *Excel* workbook.

1. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.
2. Create global variables by Typing or copying and pasting the following code inside the Visual Basic editor above Sub Launch_STK (). This will create global variables.

```
Dim app
Dim root
Dim scenario
```

3. Create a new instance of STK. Type or copy and paste the following Code within Sub Launch_STK().

```
' TASK 1
' Create new instance of STK using the CreateObject Method
Set app = CreateObject("STK.Application")
app.Visible = True
' Expose the STK application root using the Personality2 Property
Set root = app.Personality2
```



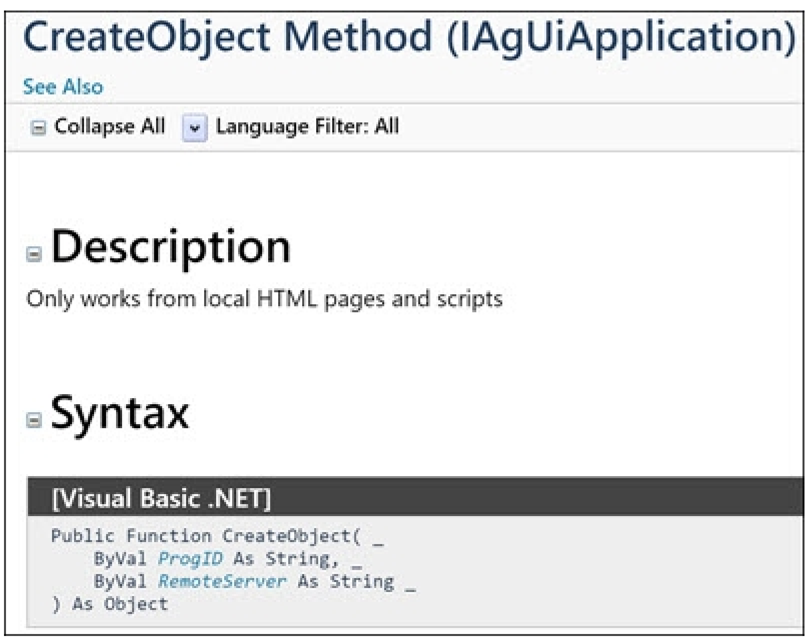
LAUNCH STK BUTTON AND TASK 1 CODE

4. Click Save STK_Excel_Workbook.xlsm (Ctrl+ S) ( ).

Understanding Task 1

Set app = CreateObject("STK.Application")

The CreateObject Method expects a string, in this case STK.Application.

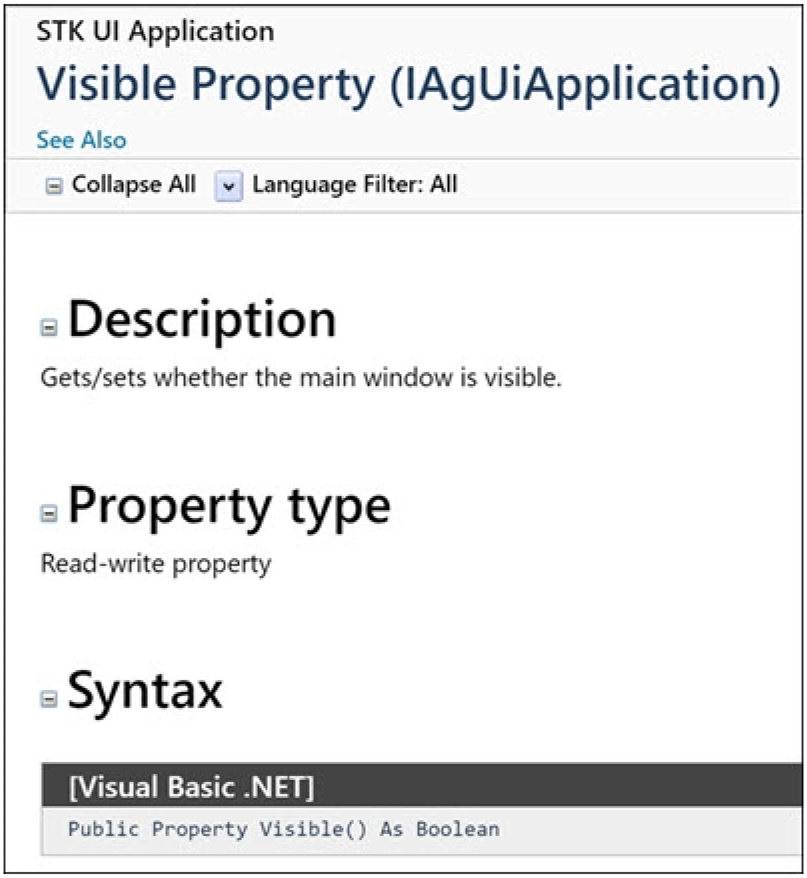


1. Bring STK Programming Help to the front.
2. Choose Library Reference in the Contents list.
3. Select Application Object Model.
4. Select STK UI Application.
5. In Classes, Select AgUiApplication on the Project Overview page.
6. In Interfaces, select IAgUiApplication on the AgUiApplication Object page.
7. In Public Methods, select CreateObject on the IAgUiApplication Interface page.
8. In Syntax, look at the [Visual Basic .NET] Syntax on the CreateObject Method (IAgUiApplication) page.

Making STK Visible

app.Visible = True

Visible Property (IAgUiApplication) makes the main window visible.



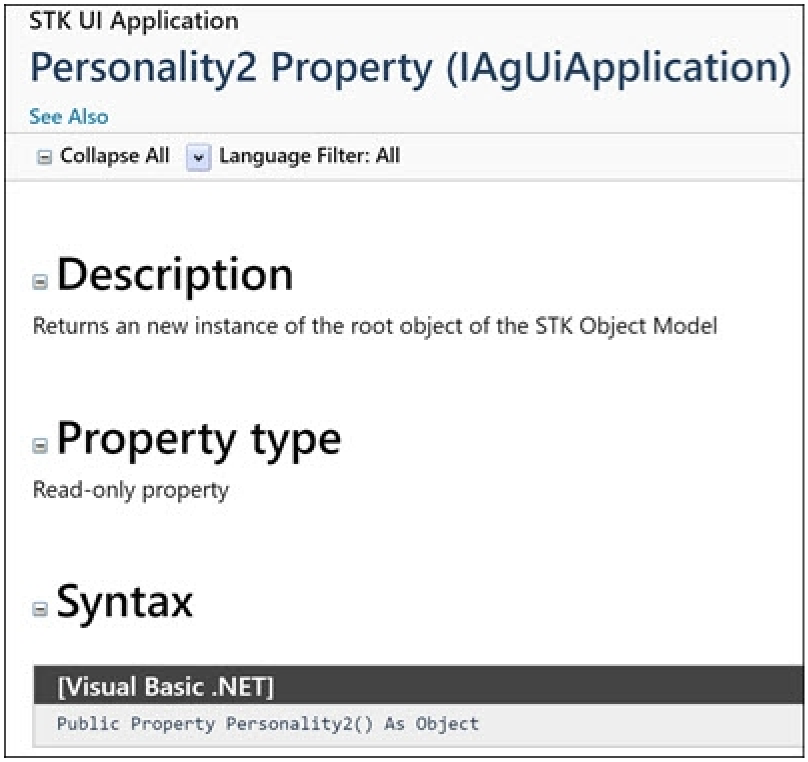
VISIBLE PROPERTY

1. Select Library Reference in the contents list.
2. Select Application Object Model.
3. Select STK UI Application.
4. Select Properties.
5. Select Visible Property (IAgUiApplication).

Exposing the STK Application Root

Set root = app.Personality2

Personality2 Property (IAgUiApplication) returns a new instance of the root object of the STK Object Model.



PERSONALITY2 PROPERTY

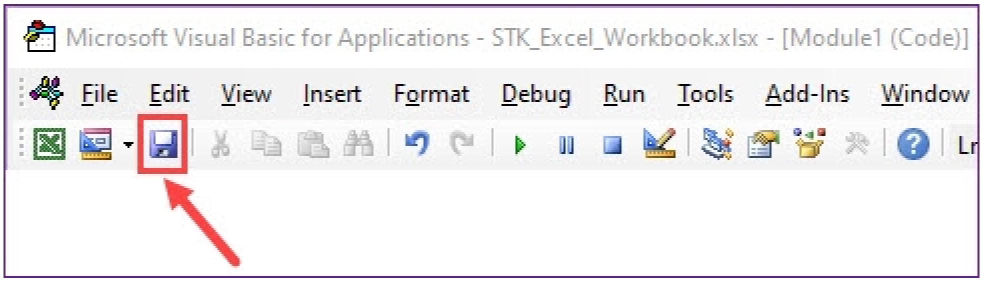
1. Select Library Reference in the contents list.
2. Select Application Object Model.
3. Select STK UI Application.
4. Select Properties.
5. Select Personality2 Property (IAgUiApplication).

Running the Sub Routine

You can run the sub routine by clicking the Launch STK button or by selecting the sub routine and clicking the green Run button.

1. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.

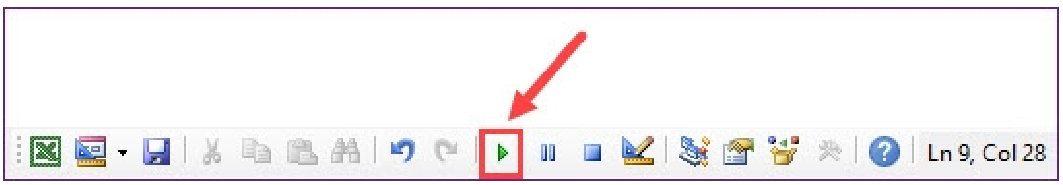
2. Click Save STK_Excel_Workbook.xlsm (Ctrl+ S) ().



SAVE BUTTON

3. Click inside the Sub Launch_STK () code.

4. Click Run Sub/UserForm (F5) ( ).



SUB/USERFORM (F5) BUTTON

The STK application window appears.

> **Note:** After testing a sub routine, when you return to the workbook and create a new button, STK will close.

Creating a New STK Scenario

After launching STK, create a new scenario and set the time period.

1. Return to the *Excel* workbook.

2. Click Insert in the Developer tab.

3. Click Button (Form Control) in the Form Controls window.

4. While in the *Excel* workbook, hold down your left mouse button and draw out a new button below the Launch STK button.

5. Type Create_Scenario in the Macro name: field when the Assign Macro dialog box opens.

6. Click **New** .

7. Return to the *Excel* workbook.

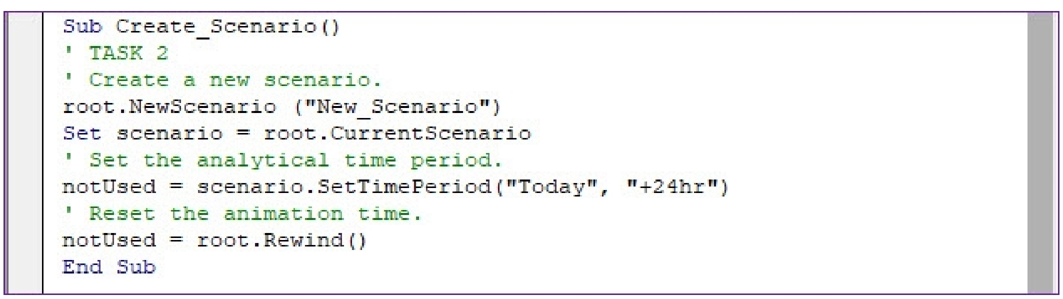
8. Change the name of Button 2 to Create Scenario.

9. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.

10. Type or copy and paste the following Code within Sub Create_Scenario ().

```
' TASK 2
' Create a new scenario.
root.NewScenario("New_Scenario")
Set scenario = root.CurrentScenario
' Set the analytical time period.
notUsed = scenario.SetTimePeriod("Today", "+24hr")
' Reset the animation time.
notUsed = root.Rewind()
```

You will create a new scenario called New_Scenario.



```
Sub Create_Scenario()
' TASK 2
' Create a new scenario.
root.NewScenario ("New_Scenario")
Set scenario = root.CurrentScenario
' Set the analytical time period.
notUsed = scenario.SetTimePeriod("Today", "+24hr")
' Reset the animation time.
notUsed = root.Rewind()
End Sub
```

Task 2 Code

11. Click Save STK_Excel_Workbook.xlsm (Ctrl+ S) (💾).

Understanding Task 2

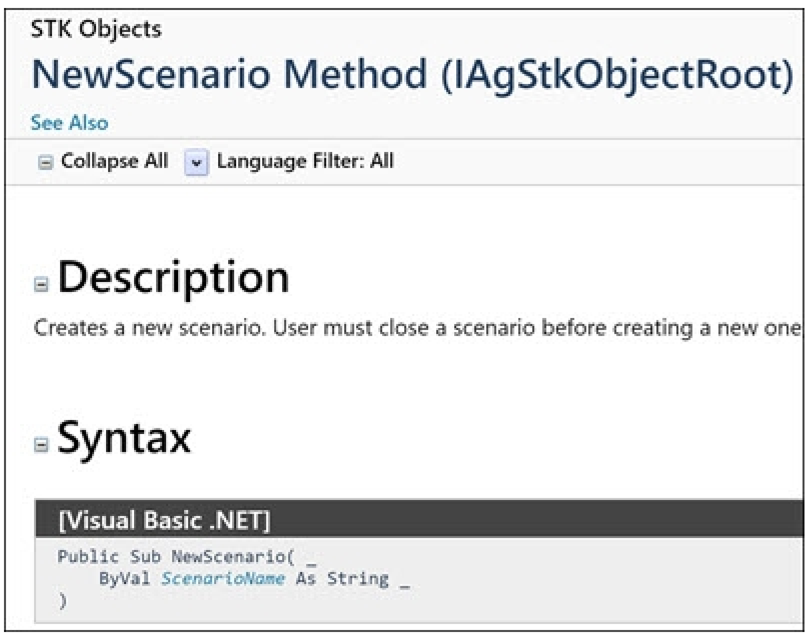
This section will show you another way to use STK Programming Help.

Understanding NewScenario Method

NewScenario Method (IAgStkObjectRoot) creates a new scenario and expects a scenario name as a string.

> **Note:** Throughout this tutorial, code from the Tasks will be in **BOLD** text. You will also find resources to understand the code's function.

You use this method in line 3 of Task 2: **root.NewScenario ("New_Scenario")**



NEWSCENARIO METHOD

1. Return to STK Programming Help.

2. Type NewScenario in the search field.

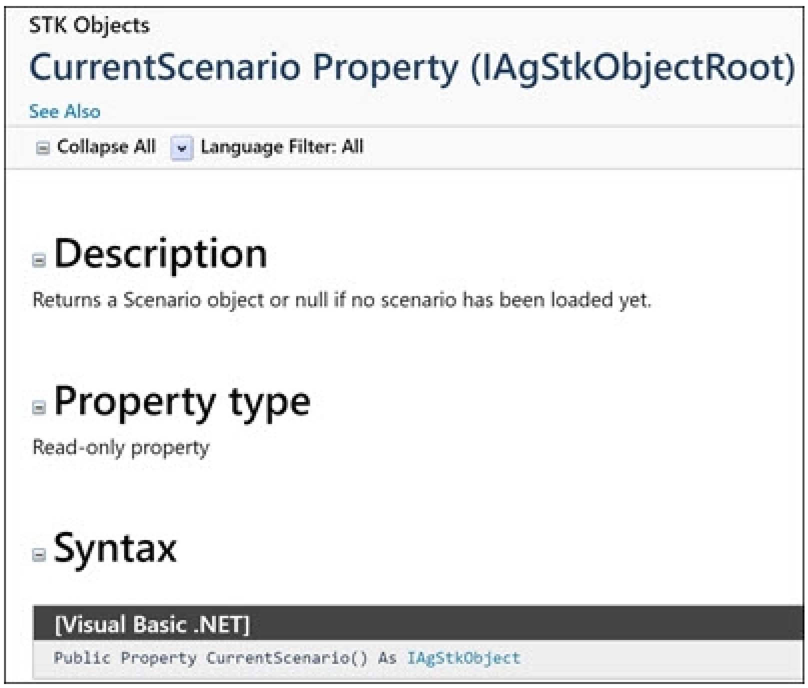
3. Click Enter.

4. Select STKObjects~IAgStkObjectRoot~NewScenario.

Understanding CurrentScenario Property

CurrentScenario Property (IAgStkObjectRoot) returns a Scenario object or null if no scenario has been loaded yet.

You use this method in line 4 of Task 2: **Set scenario = root.CurrentScenario**



CURRENTSCENARIO PROPERTY

1. Return to STK Programming Help.

2. Type CurrentScenario in the search field.

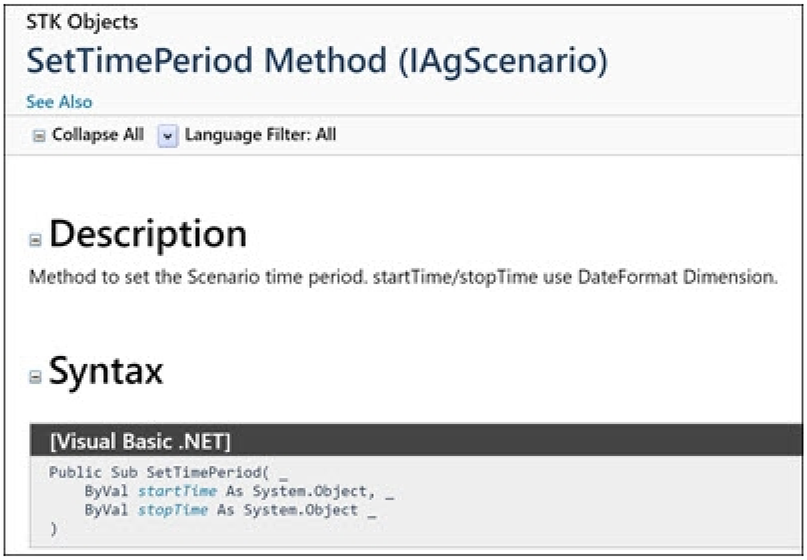
3. Click Enter.

4. Select STKObjects~IAgStkObjectRoot~CurrentScenario.

Understanding SetTimePeriod()

SetTimePeriod Method (IAgScenario) sets the Scenario time period. startTime/stopTime use DateFormat Dimension.

You use this method in line 6 of Task 2: **notUsed = scenario.SetTimePeriod("Today", "+24hr")**



SETTIMEPERIOD METHOD

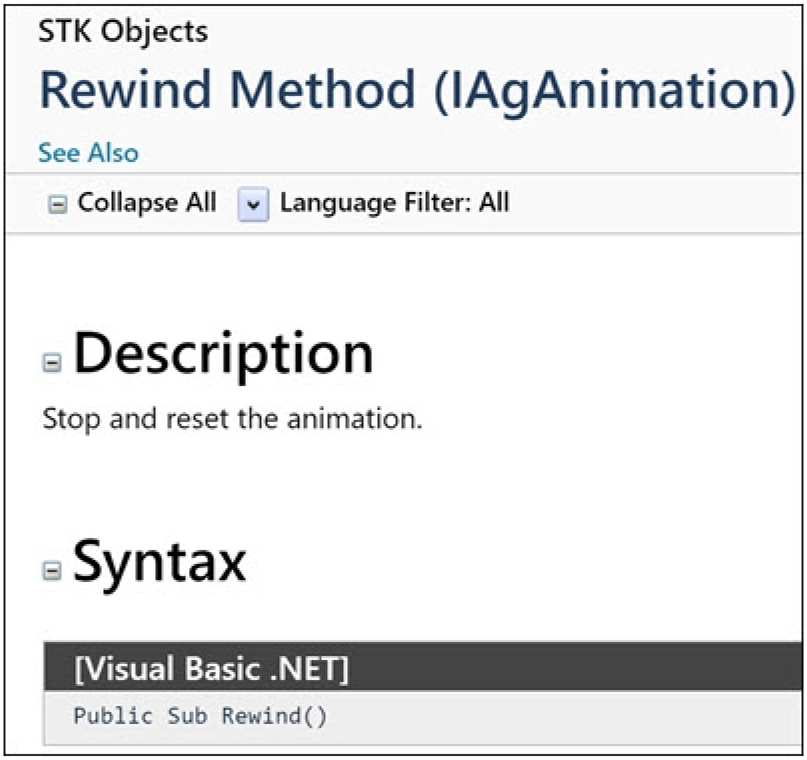
1. Return to STK Programming Help.
2. Enter SetTimePeriod in the search field.
3. Click Enter.
4. Select STKObjects~IAgScenario~SetTimePeriod.

Note: You will see throughout the code the variable notUsed. VBA expects something back even if STK doesn't return anything. Therefore, whenever you change properties of an object such as time or coordinates, you will use the variable notUsed.

Understanding Rewind()

Rewind Method (IAgAnimation) is used to stop and reset the animation.

You use this method in line 8 in Task 2: **notUsed = root.Rewind()**



REWIND METHOD

1. Return to STK Programming Help.
2. Type Rewind in the search field.
3. Click Enter.
4. Select STKObjects~IAgAnimation~Rewind.C

Summary of Task 2

In Task 2, you are creating a Scenario object named New_Scenario and setting its analysis time from midnight local time based on your time zone (Today) and running the scenario for 24 hours. Then you are essentially clicking the red Reset button in the Animation Toolbar of STK to reset your scenario time.

STK Programming Help Search Examples

These were two examples of using STK Programming Help. When you are looking at Code snippets and such, in the search window, you can type something from the Code such as Personality2 and it will provide choices to select from. It would take a long time to browse the STK Programming Help throughout this tutorial, so hyperlinks are used to simplify and speed things up. However, practice makes perfect, so feel free to search on your own.

Running Both Sub Routines

1. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.
2. Click Save (Ctrl+ S) ( ) in STK_Excel_Workbook.xlsm.
3. Bring the *Excel* workbook to the front.
4. Click **Launch STK** .
5. Click **Create Scenario** once STK opens.
6. Bring STK to the front.

Viewing the Scenario object properties

1. Right-click on New_Scenario ( ) in the Object Browser.
2. Select Properties ( ).
3. Note the Analysis Period Start: and Stop: times when the Properties Browser opens.

4. Click **Cancel** to close the New_Scenario's () properties ().

5. Look at Current Scenario Time in the Animation Toolbar. You set it for midnight local time (Today). You will see that the code reset it to the equivalent UTCG date and time.

6. Return to the *Excel* workbook.

Configuring Target1 Objects

Populate the scenario by inserting 25 Target () objects.

1. Type the following column headers into *Excel*:

Cell	Value
F1	Target Name
G1	Latitude
H1	Longitude

2. Select cell F2.

3. Enter Target.

4. Select cell G2.

5. Copy and paste the following Excel RAND function into the Formula Bar:

   =(RAND()-0.5)*180

6. Click **Enter** . The Excel RAND function returns a random number between 0 and 1. This Code will return a random number between -90 and 90.

7. Select cell H2.

8. Copy and paste the following Excel RAND function into the Formula Bar:

=(RAND()-0.5)*360

9. Click **Enter** . This Code will return a random number between -180 and 180. Your values will be different from the image.

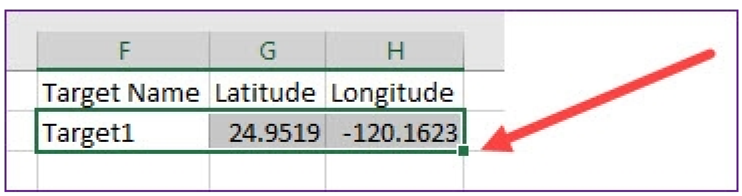
TARGET NAME, LATITUDE AND LONGITUDE

Creating Multiple Targets and Random Latitudes and Longitudes

1. Select cell F2.

2. Hold the Shift key and select cell H2.

3. Place your cursor on the small black box located at the lower right corner of cell H2.



Small Black Box

4. Hold down your left mouse button and drag the black box to cell H26 and release your mouse button. This will create 25 targets and 25 random latitudes and longitudes (your values will be different than the example).

E	F	G	H	I
	Target Name	Latitude	Longitude	
	Target1	62.0812	-108.9763	
	Target2	-54.613	47.620002	
	Target3	-87.838	-25.51989	
	Target4	-76.503	-72.50662	
	Target5	-65.974	60.854061	
	Target6	83.2393	143.94232	
	Target7	-19.379	82.644034	
	Target8	27.212	47.587597	
	Target9	63.4848	173.40258	
	Target10	73.8478	172.8944	
	Target11	55.0179	-77.26426	
	Target12	22.3721	-96.58085	
	Target13	-83.583	121.1472	
	Target14	80.4312	-62.97372	
	Target15	-81.785	-27.19727	
	Target16	-53.1	149.32333	
	Target17	-32.218	-95.1655	
	Target18	-84.244	26.042976	
	Target19	-22.422	-48.90066	
	Target20	5.82069	17.363024	
	Target21	-17.487	165.37149	
	Target22	-87.72	113.23707	
	Target23	-71.377	166.3597	
	Target24	-68.102	104.31007	
	Target25	-63.96	171.5105	

TWENTY FIVE TARGETS AND RANDOM LOCATIONS

5. Click Save (Ctrl+ S) ( ) while in the *Excel* workbook.

Inserting the Targets into STK

Insert the targets into STK using Target ( ) objects.

1. Click Insert in the Developer tab.

2. Click Button (Form Control) in the Form Controls window.

3. While in the *Excel* workbook, hold down your left mouse button and draw out a new button below the Create Scenario button.

4. Type Insert_Targets in the Macro name: field of the Assign Macro dialog box.

5. Click New .

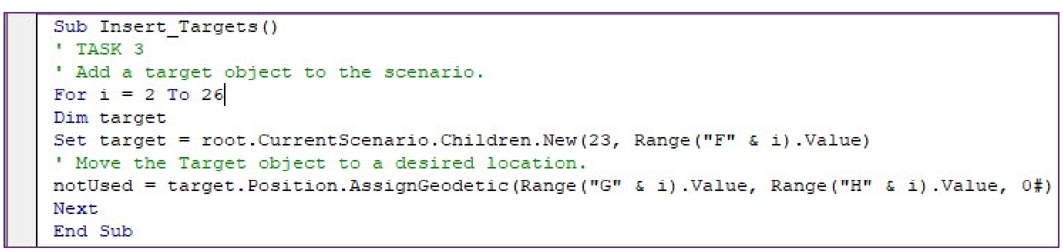
6. Return to the *Excel* workbook.

7. Change the name of Button 3 to Insert Targets.

8. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.

9. Type or copy and paste the following Code within Sub Insert_Targets().

```
' TASK 3
' Add a target object to the scenario.
For i = 2 to 26
Dim target
Set target = root.CurrentScenario.Children.New(23, Range("F" & i).Value)
' Move the Target object to a desired location.
notUsed = target.Position.AssignGeodetic(Range("G" & i).Value, Range("H" &
i).Value, 0.0)
Next
```



```
Sub Insert_Targets()
' TASK 3
' Add a target object to the scenario.
For i = 2 To 26
Dim target
Set target = root.CurrentScenario.Children.New(23, Range("F" & i).Value)
' Move the Target object to a desired location.
notUsed = target.Position.AssignGeodetic(Range("G" & i).Value, Range("H" & i).Value, 0#)
Next
End Sub
```

TASK 3 CODE

10. Click Save (Ctrl+ S) (💾) in STK_Excel_Workbook.xlsm.

Understanding Task 3

Review the following sections to learn more about each line of Task 3 and discover resources in the STK Programming Help.

Understanding how to loop through rows in the code

You are looping through rows 2 to 26 of your Excel workbook. You create a new Target object on each line for 25 targets total.

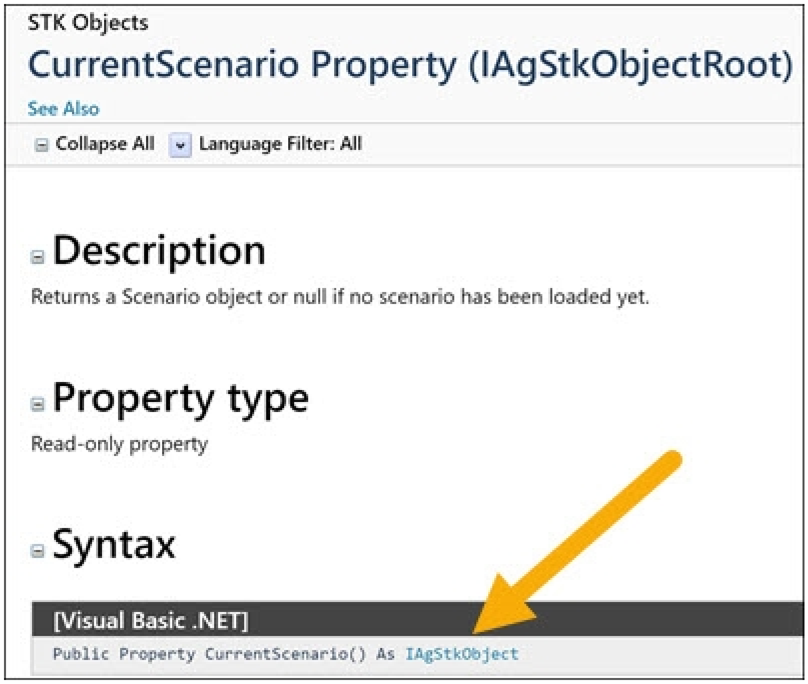
You use a loop in line 3 of Task 3: **For i = 2 to 26**

Understanding the CurrentScenario Method

You use the CurrentScenario Method in line 5 of Task 3: **Set target = root.CurrentScenario.Children.New(23, Range("F" & i).Value)**

You will navigate to the CurrentScenario Method in the STK Programming Help for more information.

1. Return to STK Programming Help.
2. Type currentscenario in the search field.
3. Click **Enter** .
4. Select STKObjects~IAgStkObjectRoot~CurrentScenario from the search results.



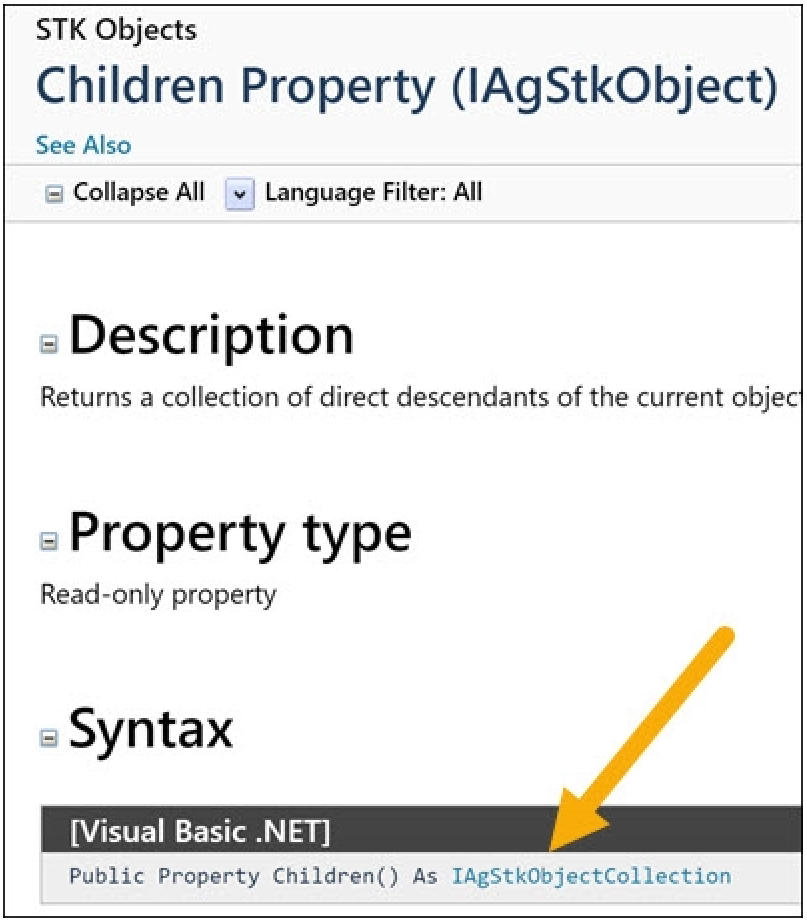
SELECT IAGSTKOBJECT

5. Select IAgStkObject in the Visual Basic .NET Syntax list.
6. Select Children in Public Properties.

Children Property

Children Property (IAgStkObject) returns a collection of direct descendants of the current object.

1. Select IAgStkObjectCollection from the Visual Basic .NET Syntax list.
2. Select New In Public Methods.



SELECT IAGSTKOBJECTCOLLECTION

New Method

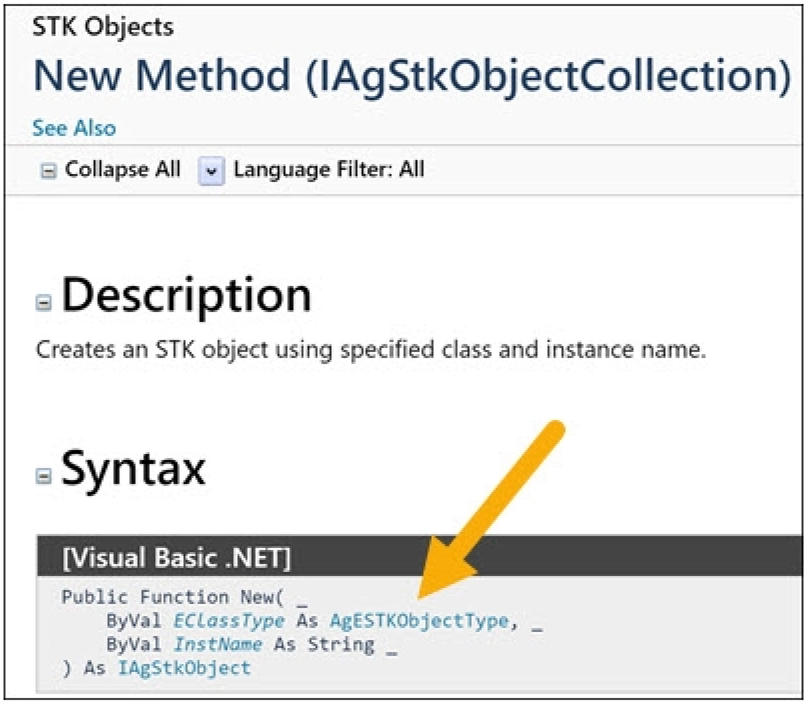
New Method (IAgStkObjectCollection) creates an STK object using specified class and instance name.

1. Select AgESTKObjectType from the Visual Basic .NET Syntax list.

   AgESTKObjectType Enumeration shows the object type enumerations, associated value and the STK objects.

2. Scroll down the Member list until you locate eTarget. To insert a new Target ( ) object, you can use eTarget or the value 23. Your code uses the value 23.

   Next, STK wants a string for the name. You want the name in cell F2. To use all the target names, in VBA, you use Range. You want cell F and the ampersand (&) allows you to concatenate strings. It will start in F2 and finish in F26.



SELECT AGESTKOBJECTTYPE

Assigning Locations of objects

In short, the Position Property gets the position of the target. The AssignGeodetic Method is a helper method to assign the position using the Geodetic representation. Learn more about the Position Property (IAgTarget) and the AssignGeodetic Method (IAgPosition) in the STK Programming Help.

You use both of these method in line 7 of Task 3: **notUsed = target.Position.AssignGeodetic(Range("G" & i).Value, Range("H" & i).Value, 0.0)**

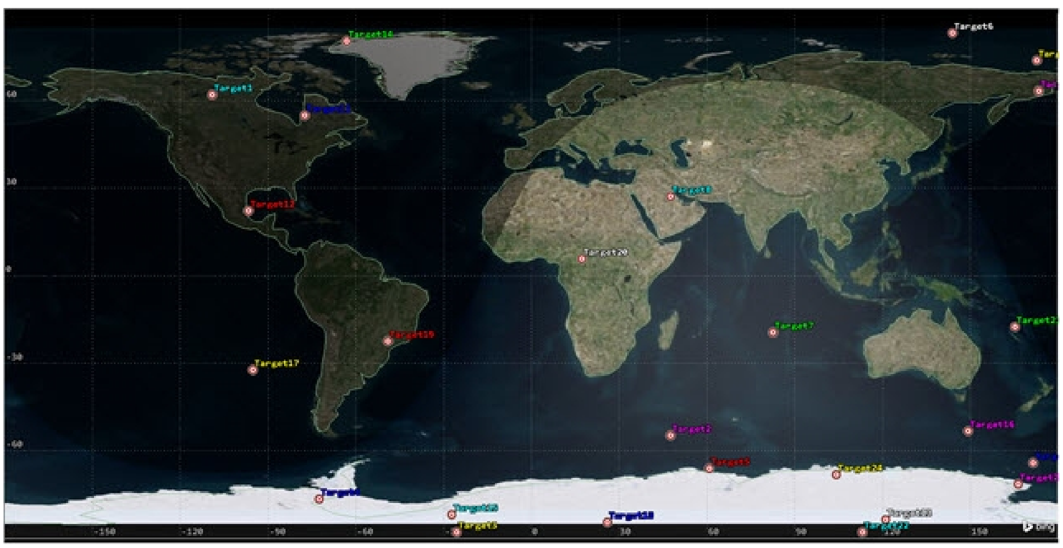
Within the AssignGeodetic method:

- **Range("G" & i).Value** will read cells G2 though G26 for the latitudes.
- **Range("H" & i).Value, 0.0)** will read cells H2 though H26 for the longitudes. The altitude is 0.0 for all the targets which will place them on top of the WGS84 ellipsoid if you don't have terrain or on top of the terrain if you're using terrain such as Terrain Server. In the Code, *Excel* converts the value 0.0 is converted to 0#. (Don't worry about it.)

Running all three sub routines

1. Bring the *Excel* workbook to the front.
2. Click **Launch STK** in the *Excel* workbook.
3. Click **Create Scenario** once STK opens.
4. After the scenario is created, click **Insert Targets** .
5. Bring STK to the front.

   You created an instance of STK, created a scenario with a 24 hour analysis period and inserted 25 random Target objects around the Earth.



2D GRAPHICS VIEW OF RANDOM TARGETS AROUND THE EARTH

Inserting a Satellite Object into STK

You have launched STK, created a new scenario, set the time period and inserted 25 randomly placed Target ( ) objects. Now you will insert and propagate a Satellite ( ) object.

1. Return to the *Excel* workbook.

2. Click **Insert** in the Developer tab.

3. Click Button (Form Control) in the Form Controls window.

4. While in the *Excel* workbook, hold down your left mouse button and draw out a new button below the Insert Targets button.

5. Type Insert_Satellite in the Macro name: field of the Assign Macro dialog box.

6. Click **New** .

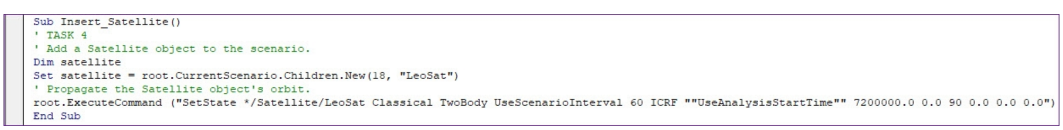
7. Bring the *Excel* workbook to the front.

8. Change the name of Button 4 to Insert Satellite.

9. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.

10. Type or copy and paste the following Code within Sub Insert_Satellite ().

```
' TASK 4
' Add a Satellite object to the scenario.
Dim satellite
Set satellite = root.CurrentScenario.Children.New(18, "LeoSat")
' Propagate the Satellite object's orbit.
root.ExecuteCommand ("SetState */Satellite/LeoSat Classical TwoBody
UseScenarioInterval 60 ICRF ""UseAnalysisStartTime"" 7200000.0 0.0 90 0.0
0.0 0.0")
```



```
Sub Insert_Satellite()
' TASK 4
' Add a Satellite object to the scenario.
Dim satellite
Set satellite = root.CurrentScenario.Children.New(18, "LeoSat")
' Propagate the Satellite object's orbit.
root.ExecuteCommand ("SetState */Satellite/LeoSat Classical TwoBody UseScenarioInterval 60 ICRF ""UseAnalysisStartTime"" 7200000.0 0.0 90 0.0 0.0 0.0")
End Sub
```

TASK 4 CODE

11. Click Save (Ctrl+ S) () in STK_Excel_Workbook.xlsm.

Understanding Task 4

Review the following sections to learn how each line of Task 4 works.

Understanding the Children Property in Task 4

You use the Children property to insert a Satellite ( ) object in this case. This code uses the value 18 which loads a Satellite ( ) object into your scenario called LeoSat. Previously, you used similar code to insert a Target ( ) object into the scenario.

You used this property in line 4 of Task 4: **Set satellite = root.CurrentScenario.Children.New(18, "LeoSat")**

Understanding the ExecuteCommand() Method

You use the ExecuteCommand Method to propagate the Satellite ( ) object. In general, the method executes a custom CONNECT action. Learn more about the connect command ExecuteCommand Method (IAgStkObjectRoot) in the STK Programming Help.

You used this method in line 6 of Task 4: **root.ExecuteCommand ("SetState */Satellite/LeoSat Classical TwoBody UseScenarioInterval 60 ICRF ""UseAnalysisStartTime"" 7200000.0 0.0 90 0.0 0.0 0.0")**

SetState Connect Command

Look at the Alphabetical Listing of Connect Commands to understand the SetState connect command.

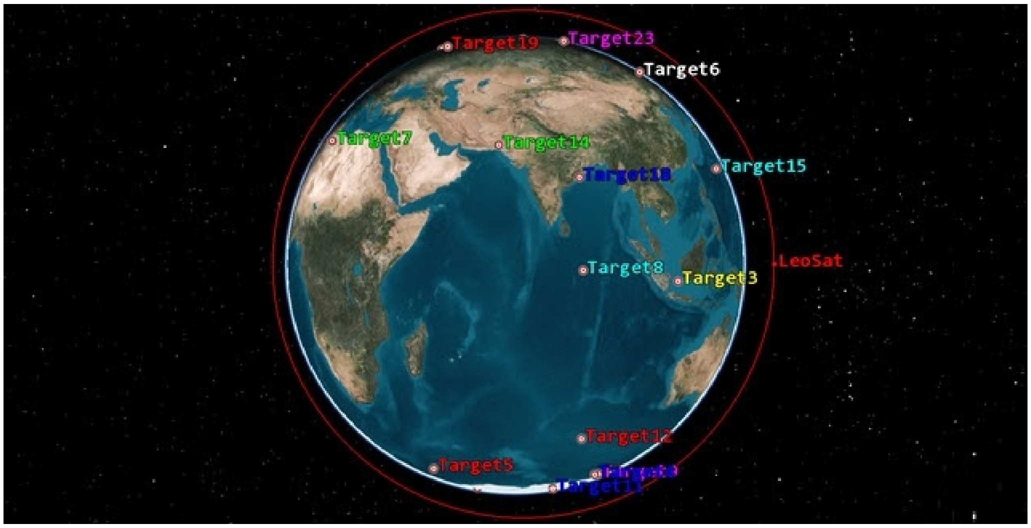
1. Return to STK Programming Help.
2. Choose Library Reference in the Contents list.
3. Select Connect Command Library.

4. Click Alphabetical Listing of Connect Commands from the Connect Command Listings page.
5. Click S at the top of the Alphabetical Listing page.
6. Select the SetState Classical command.
7. Scroll through the SetState Classical page and note the following:
   - Syntax will help you understand the input values of your SetState command.
   - The description chart explains each input and its associated unit.
   - In the Examples section, there are multiple examples that can be copied and edited for your particular scenario.

Running all four sub routines

1. Return to the *Excel* workbook.
2. Click **Launch STK** .
3. Click **Create Scenario** once STK opens.
4. After the scenario is created, click **Insert Targets** .
5. After the targets are inserted, click **Insert Satellite** .
6. Bring STK to the front.

You created an instance of STK, a scenario with a 24 hour analysis period, inserted 25 random Target ( ) objects around the Earth and inserted and propagated a Satellite ( ) object.



3D VIEW OF RANDOM TARGET OBJECTS AND SATELLITE OBJECT

Creating an Access

Determine when the LeoSat ( ) can access Target1 ( ).

1. Return to the *Excel* workbook.
2. Click **Insert** in the Developer tab.
3. Click Button (Form Control) in the Form Controls window.
4. While in the *Excel* workbook, hold down your left mouse button and draw out a new button below the Insert Satellite button.
5. Type Compute_Access in the Macro name: field of the Assign Macro dialog box.
6. Click **New** .
7. Bring the *Excel* workbook to the front.
8. Rename Button 5 to Compute Access.
9. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.
10. Type or copy and paste the following Code within Sub Compute_Access ().

```
' TASK 5
' Compute Access between the satellite and the target
Dim sat
Set sat = root.GetObjectFromPath("Satellite/LeoSat")
Dim tar1
Set tar1 = root.GetObjectFromPath("Target/Target1")
Dim access
Set access = sat.GetAccessToObject(tar1)
'Compute access
access2 = access.ComputeAccess()
```

Understanding Task 5

Review these sections to understand more about Task 5.

Understanding GetObjectFromPath()

In short, the method gets the object instance that matches the path provided. Learn more about the GetObjectFromPath Method (IAgStkObjectRoot) in the STK Programming Help.

You use this method in lines 4 and 6 from Task 5:

Set sat = root.GetObjectFromPath("Satellite/LeoSat")

Set tar1 = root.GetObjectFromPath("Target/Target1")

Understanding the GetAccessToObject()

In short, the method returns an IAgStkAccess object to compute access to. Learn more about the GetAccessToObject Method (IAgStkObject) in the STK Programming Help.

You use this method in line 8 from Task 5: **Set access = sat.GetAccessToObject(tar1)**

Understanding the ComputeAccess() Method

In short, the ComputeAccess() recomputes the access between two objects. Learn more about the ComputeAccess Method (IAgStkAccess) in the STK Programming Help.

You use this method in line 10 in Task 5: **access2 = access.ComputeAccess()**

Data Providers

The content of a report or graph is generated from the selected data providers for the report or graph style. You can view data providers, groups and elements when using the Report & Graph Manager inside of STK. Data providers are also broken out in detail in STK Programming Help.

1. Return to STK Programming Help.
2. Select Library Reference in the Contents list.
3. Select Data Providers Reference.
4. On the Data Providers by Object page, you can spend a lot of time looking at an object's data providers, groups and elements.
5. Keep this page open.

Retrieve and View the Access Data in Excel

You created an access from LeoSat ( ) to Target1 ( ). Retrieve and view the access data in *Excel*.

1. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.
2. Type or copy and paste the following Code at the bottom of the Sub Compute_Access().

```
 ' TASK 6
' Pull the data of interest out of the access object
Dim dp
Set dp = access.DataProviders("Access Data")
Dim results
Set results = dp.Exec(scenario.StartTime, scenario.StopTime)
accessNumber = results.DataSets(0).GetValues()
accessStart = results.DataSets(1).GetValues()
accessStop = results.DataSets(2).GetValues()
accessDuration = results.DataSets(3).GetValues()
' Create columns
Range("J1") = results.DataSets(0).ElementName
Range("K1") = results.DataSets(1).ElementName
Range("L1") = results.DataSets(2).ElementName
Range("M1") = results.DataSets(3).ElementName
' Write the data into Excel.
For i = 0 To UBound(accessNumber)
Range("J" & i + 2) = accessNumber(i)
Range("K" & i + 2) = accessStart(i)
Range("L" & i + 2) = accessStop(i)
Range("M" & i + 2) = accessDuration(i)
Next
```

3. Click Save STK_Excel_Workbook.xlsm ().

```
Sub Compute_Access()
' Task 5
' Compute Access between the satellite and the target
Dim sat
Set sat = root.GetObjectFromPath("Satellite/LeoSat")
Dim tarl
Set tarl = root.GetObjectFromPath("Target/Target1")
Dim access
Set access = sat.GetAccessToObject(tarl)
'Compute access
access2 = access.ComputeAccess()
' Task 6
' Pull the data of interest out of the access object
Dim dp
Set dp = access.DataProviders("Access Data")
Dim results
Set results = dp.Exec(scenario.StartTime, scenario.StopTime)
accessNumber = results.DataSets(0).GetValues()
accessStart = results.DataSets(1).GetValues()
accessStop = results.DataSets(2).GetValues()
accessDuration = results.DataSets(3).GetValues()
' Create columns
Range("J1") = results.DataSets(0).ElementName
Range("K1") = results.DataSets(1).ElementName
Range("L1") = results.DataSets(2).ElementName
Range("M1") = results.DataSets(3).ElementName
' Write the data into Excel.
For i = 0 To UBound(accessNumber)
Range("J" & i + 2) = accessNumber(i)
Range("K" & i + 2) = accessStart(i)
Range("L" & i + 2) = accessStop(i)
Range("M" & i + 2) = accessDuration(i)
Next
End Sub
```

TASKS 5 AND 6

Understanding Task 6

Review the sections to learn about the different methods and properties in Task 6. Also, you will discover resources in the STK Programming Help to understand these methods and properties further.

Understing the DataProviders Property

The DataProviders Property returns the object representing a list of available data providers for the object. Learn more about the DataProviders Property (IAgStkAccess) in the STK Programming Help.

You use this property in line 4 of Task 6: **Set dp = access.DataProviders("Access Data")**

1. Return to STK Programming Help.
2. Select Access on the Data Providers by Object page. This page provides data providers available for the Access object.
3. Select Access Data in the Available Data Providers list. Access Data is the specified data provider.
4. Select Access in the Data Provider Variants list.
5. Look at the Data Provider Elements list to understand the following code.

Understanding the Exec() Method

The Exec Method computes the data within a specified Start and Stop time. Learn more about the Exec Method (IAgDataPrvTimeVar) in the STK Programming Help.

You use this method in line 6 of Task 6: **Set results = dp.Exec(scenario.StartTime, scenario.StopTime)**

Understanding the DataSets() Property and the GetValues Method

The DataSets() Property returns a collection of data sets within a specified interval. The GetValues retrieves an array of values of the elements in the dataset. In this instance, you're creating an access from the satellite to the target based on the scenario start and stop times.

When pulling data from the data provider elements list, it follows the sequence as seen in the list. For example, the first element, Access Number, is 0 (zero). Start Time is 1 (one), Stop Time is 2 (two) and Duration is 3 (three). In the code, accessNumber = results.DataSets(0).GetValues() simply means that you are you are pulling the results from the data provider (Access Data) and then the data provider element Access Number.

You can learn more about the DataSets Property (IAgDrInterval) and the GetValues Method (IAgDrDataSet) in the STK Programming Help.

You use this property and method in lines 7 to 10 of Task 6:

accessNumber = results.DataSets(0).GetValues()

accessStart = results.DataSets(1).GetValues()

accessStop = results.DataSets(2).GetValues()

accessDuration = results.DataSets(3).GetValues()

Understanding the ElementName Property

You use the DataSets() Property again, but you pair that property with a new one. The ElementName Property returns the name of the dataset. In Task 6, you are writing the element names as headers for columns J1 through M1. Learn more about the ElementName Property (IAgDrDataSet) in the STK Programming Help.

You use this property in lines 12 to 15 of Task 6:

Range("J1") = results.DataSets(0).ElementName

Range("K1") = results.DataSets(1).ElementName

Range("L1") = results.DataSets(2).ElementName

Range("M1") = results.DataSets(3).ElementName

Understanding filling the data in your table

You use a loop to add data to your table in line 17 to 21 in Task 6:

For i = 0 To UBound(accessNumber)

Range("J" & i + 2) = accessNumber(i)

Range("K" & i + 2) = accessStart(i)

Range("L" & i + 2) = accessStop(i)

Range("M" & i + 2) = accessDuration(i)

You will loop through all the data that it returns and write it to the appropriate cell.

Run all five sub routines

1. Bring the *Excel* workbook to the front.

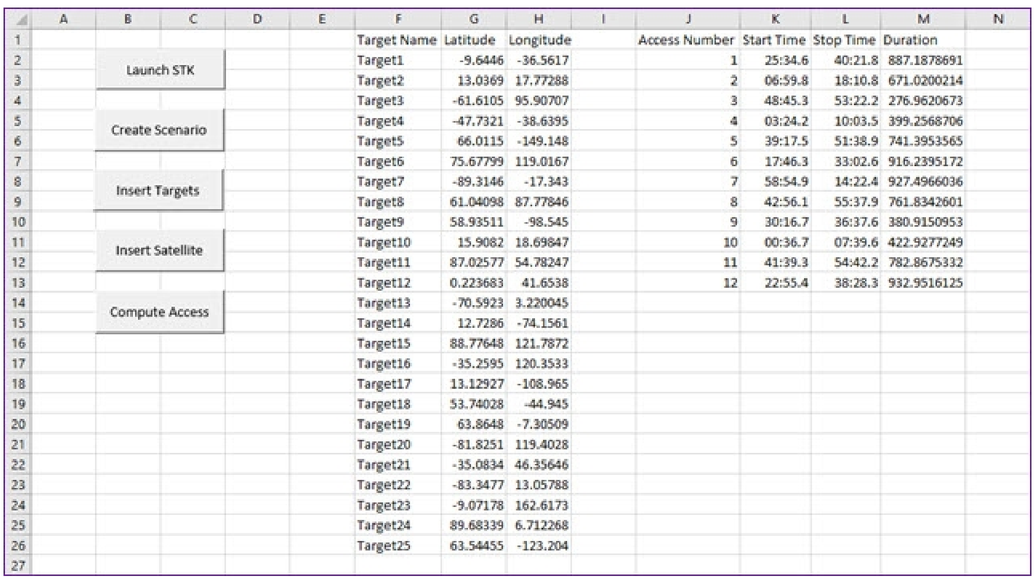
2. Click **Launch STK** .

3. Click **Create Scenario** once STK opens.

4. After the scenario is created, click **Insert Targets** .

5. After the targets are inserted, click **Insert Satellite** .

6. After the satellite is inserted, click **Compute Access** . Your data will look similar to but different than the following example.



Target Name	Latitude	Longitude	Access Number	Start Time	Stop Time	Duration
Target1	-9.6446	-36.5617	1	25:34.6	40:21.8	887.1878691
Target2	13.0369	17.77288	2	06:59.8	18:10.8	671.0200214
Target3	-61.6105	95.90707	3	48:45.3	53:22.2	276.9620673
Target4	-47.7321	-38.6395	4	03:24.2	10:03.5	399.2568706
Target5	66.0115	-149.148	5	39:17.5	51:38.9	741.3953565
Target6	75.67799	119.0167	6	17:46.3	33:02.6	916.2395172
Target7	-89.3146	-17.343	7	58:54.9	14:22.4	927.4966036
Target8	61.04098	87.77846	8	42:56.1	55:37.9	761.8342601
Target9	58.93511	-98.545	9	30:16.7	36:37.6	380.9150953
Target10	15.9082	18.69847	10	00:36.7	07:39.6	422.9277249
Target11	87.02577	54.78247	11	41:39.3	54:42.2	782.8675332
Target12	0.223683	41.6538	12	22:55.4	38:28.3	932.9516125
Target13	-70.5923	3.220045				
Target14	12.7286	-74.1561				
Target15	88.77648	121.7872				
Target16	-35.2595	120.3533				
Target17	13.12927	-108.965				
Target18	53.74028	-44.945				
Target19	63.8648	-7.30509				
Target20	-81.8251	119.4028				
Target21	-35.0834	46.35646				
Target22	-83.3477	13.05788				
Target23	-9.07178	162.6173				
Target24	89.68339	6.712268				
Target25	63.54455	-123.204				

BUTTONS, TARGETS, AND ACCESS DATA

Format cells

Excel formats the start and stop times differently than SKT (e.g. day, month, year, time). You can select the cells containing the start and stop times, right-click on the selection, open the Format Cells option and set the format to dd mmm yyyy hh:mm:ss.000. Or you can use the following Code.

1. Bring the Microsoft Visual Basic for Applications - [Module 1 (Code)] window to the front.

2. Type or copy and paste the following Code at the bottom of the Sub Compute_Access().

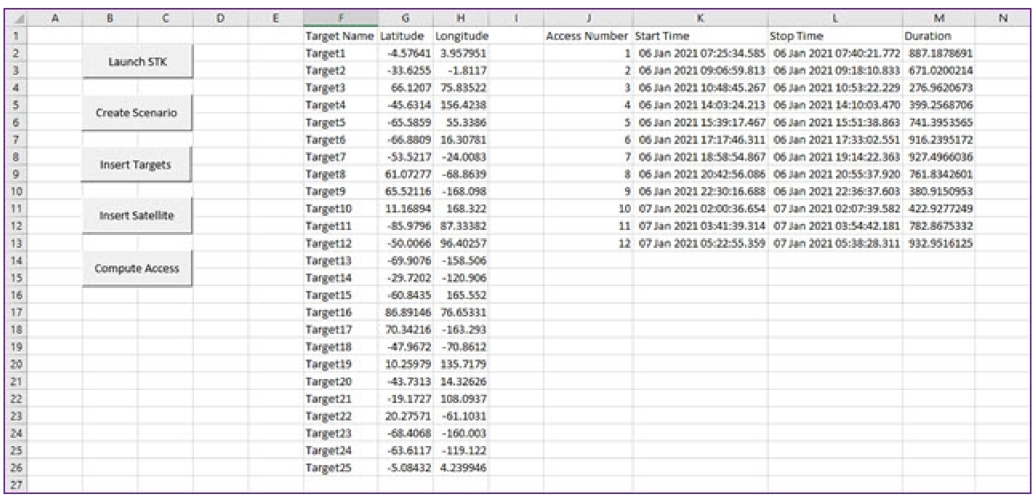
```
ActiveSheet.Columns("K").Select
Selection.NumberFormat = "dd mmm yyyy hh:mm:ss.000"
ActiveSheet.Columns("L").Select
Selection.NumberFormat = "dd mmm yyyy hh:mm:ss.000"
```

3. Click Save STK_Excel_Workbook.xlsm (Ctrl+ S) ().

4. Bring the *Excel* workbook to the front.

5. Click Compute Access . Your data will look similar to but different than the following example.

6. Click Save ().



Target Name	Latitude	Longitude	Access Number	Start Time	Stop Time	Duration
Target1	-4.57641	3.957951	1	06 Jan 2021 07:25:34.585	06 Jan 2021 07:40:21.772	887.1878691
Target2	-33.6255	-1.8117	2	06 Jan 2021 09:06:59.813	06 Jan 2021 09:18:10.833	671.0200214
Target3	66.1207	75.83522	3	06 Jan 2021 10:48:45.267	06 Jan 2021 10:53:22.229	276.9620673
Target4	-45.6314	156.4238	4	06 Jan 2021 14:03:24.213	06 Jan 2021 14:10:03.470	399.2568706
Target5	-65.5859	55.3386	5	06 Jan 2021 15:39:17.467	06 Jan 2021 15:51:38.863	741.3953565
Target6	-66.8809	16.30781	6	06 Jan 2021 17:17:46.311	06 Jan 2021 17:33:02.551	916.2395172
Target7	-53.5217	-24.0083	7	06 Jan 2021 18:58:54.867	06 Jan 2021 19:14:22.363	927.4966036
Target8	61.07277	-68.8639	8	06 Jan 2021 20:42:56.086	06 Jan 2021 20:55:37.920	761.8342601
Target9	65.52116	-168.098	9	06 Jan 2021 22:30:16.688	06 Jan 2021 22:36:37.603	380.9150953
Target10	11.16894	168.322	10	07 Jan 2021 02:00:36.654	07 Jan 2021 02:07:39.582	422.9277249
Target11	-85.9796	87.33382	11	07 Jan 2021 03:41:39.314	07 Jan 2021 03:54:42.181	782.8675332
Target12	-50.0066	96.40257	12	07 Jan 2021 05:22:55.359	07 Jan 2021 05:38:28.311	932.9516125
Target13	-69.9076	-158.506				
Target14	-29.7202	-120.906				
Target15	-60.8435	165.552				
Target16	86.89146	76.65331				
Target17	70.34216	-163.293				
Target18	-47.9672	-70.8612				
Target19	10.25979	135.7179				
Target20	-43.7313	14.32626				
Target21	-19.1727	108.0937				
Target22	20.27571	-61.1031				
Target23	-68.4068	-160.003				
Target24	-63.6117	-119.122				
Target25	-5.08432	4.239946				

REFORMATTED CELLS

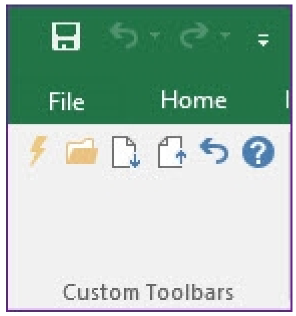
STK Excel Add-in

At the beginning of the tutorial, you downloaded and installed the STK Excel Add-in. Use that now.

1. Select the Add-ins tab.

Custom Toolbars

If you're using the STK Excel Add-in, in the *Excel* ribbon, you should see the Custom Toolbars.



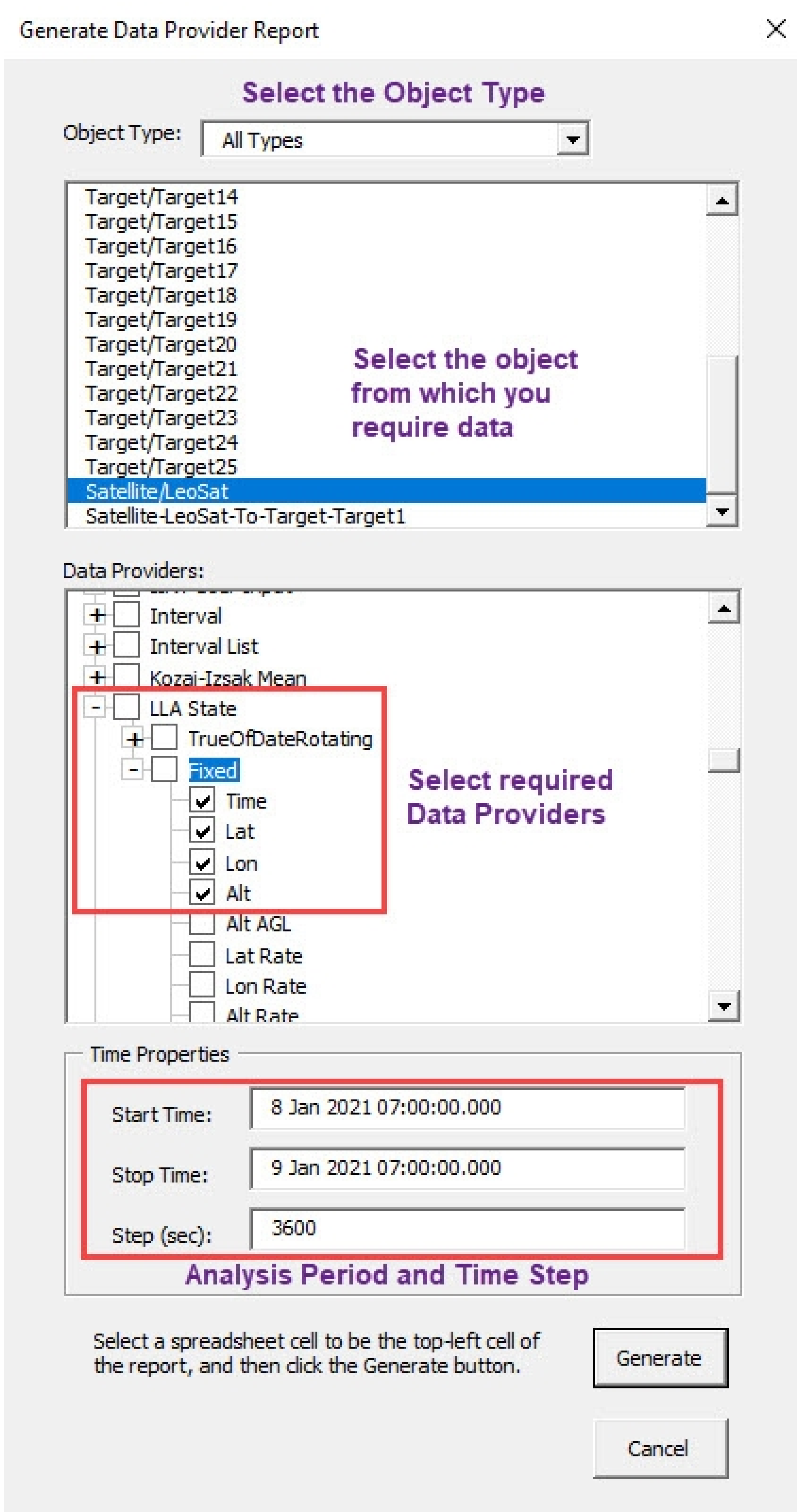
CUSTOM TOOLBAR

Button	Function
	Create or Attach to STK 12
	Open or Close a scenario 12
	Extract Data From an STK 12 Data Provider
	Insert Data Into STK 12
	Undo the last Get Data operation
	About this Add-in

Attaching the Excel Workbook to STK

Since you already have a running instance of STK, you can attach *Excel* to your scenario.

1. Select cell P in the *Excel* workbook. You want an empty cell plus three empty cells to the right. You will be choosing four elements.
2. Click Create or Attach to STK 12 () from the Custom Toolbars.
3. Select Attach to an existing STK 12 application instance.
4. Click **OK** to close the information window.
5. Click Extract Data From an STK 12 Data Provider () to open the Generate Data Provider Report tool.



Generate Data Provider Report
Select the Object Type
Object Type:
All Types
Target/Target14
Target/Target15
Target/Target16
Target/Target17
Target/Target18
Target/Target19
Target/Target20
Target/Target21
Target/Target22
Target/Target23
Target/Target24
Target/Target25
Satellite/LeoSat
Satellite-LeoSat-To-Target-Target1
Select the object from which you require data
Data Providers:
Interval
Interval List
Kozai-Izsak Mean
LLA State
TrueOfDateRotating
Fixed
Time
Lat
Lon
Alt
Alt AGL
Lat Rate
Lon Rate
Alt Rate
Select required Data Providers
Time Properties
Start Time:
8 Jan 2021 07:00:00.000
Stop Time:
9 Jan 2021 07:00:00.000
Step (sec):
3600
Analysis Period and Time Step
Select a spreadsheet cell to be the top-left cell of the report, and then click the Generate button.
Generate
Cancel

Selecting your data providers

1. Select Satellite/LeoSat from the object list.
2. Expand (⊞) LLA State (Data Provider) in the Data Providers: list.
3. Expand (⊞) Fixed.
4. Select the following data provider elements.
    - Time
    - Lat
    - Lon
    - Alt
5. Use the default Start Time and Stop Time values.
6. Change Step (sec): to 3600. This will make the data easier to read.
7. Click **Generate** .
8. Close the Generate Data Provider Report tool.
9. You can expand columns P/Q/R/S in the *Excel* workbook if desired to see all of the data.

    You can see the Time, Latitude, Longitude, and Altitude of the satellite in one hour increments over the 24 hour analysis period.

P	Q	R	S
Time	Lat	Lon	Alt
8 Jan 2021 07:00:00.000000000	0.115972847	147.2143758	821.8630869
8 Jan 2021 08:00:00.000000000	-33.42654976	-47.8267562	828.3178907
8 Jan 2021 09:00:00.000000000	66.54946547	117.1319682	839.8392323
8 Jan 2021 10:00:00.000000000	-80.47567978	102.0920112	842.6578416
8 Jan 2021 11:00:00.000000000	47.43475911	-92.94971583	833.4225308
8 Jan 2021 12:00:00.000000000	-14.19107732	72.00908672	823.1390751
8 Jan 2021 13:00:00.000000000	-19.14989215	-123.0320959	824.1486094
8 Jan 2021 14:00:00.000000000	52.36407552	41.92662961	835.2355602
8 Jan 2021 15:00:00.000000000	-85.38164177	-153.1169078	843.107992
8 Jan 2021 16:00:00.000000000	61.63328025	-168.1548114	838.3919416
8 Jan 2021 17:00:00.000000000	-28.47852499	-3.196174492	826.6965781
8 Jan 2021 18:00:00.000000000	-4.84746341	161.76262	822.0145521
8 Jan 2021 19:00:00.000000000	38.13896522	-33.27858558	829.9805717
8 Jan 2021 20:00:00.000000000	-71.23239599	131.6799696	841.0189915
8 Jan 2021 21:00:00.000000000	75.79762124	116.6400718	841.9511827
8 Jan 2021 22:00:00.000000000	-42.73129233	-78.40150251	831.6690006
8 Jan 2021 23:00:00.000000000	9.461894055	86.557322	822.4366404
9 Jan 2021 00:00:00.000000000	23.87391451	-108.4838062	825.3435934
9 Jan 2021 01:00:00.000000000	-57.05841454	56.47505059	836.8902435
9 Jan 2021 02:00:00.000000000	89.94245776	41.49611666	843.247664
9 Jan 2021 03:00:00.000000000	-56.94292064	-153.606884	836.8507426
9 Jan 2021 04:00:00.000000000	23.75766809	11.35198904	825.3117024
9 Jan 2021 05:00:00.000000000	9.578341976	176.3108913	822.4507173
9 Jan 2021 06:00:00.000000000	-42.8471597	-18.73022281	831.7120916
9 Jan 2021 07:00:00.000000000	75.91285224	146.2284742	841.9717024

DATA PROVIDER REPORT

Summary

You began by viewing a small portion of the STK Programming Help pages. Then you performed the following:

- Downloaded and installed the STK Excel Add-in.
- Opened *Excel* and enabled the Developer tab and turned on the STK Excel Add-in.
- After closing and then opening *Excel*, you created an *Excel* Macro-Enabled Workbook (*.xlsm).
- Created the first button and code which launched an instance of STK.

- Created the second button and code to create a new Scenario object with a run time of 24 hours and reset the scenario to the new analysis time period.
- In the *Excel* workbook, you created three columns: Target Name, Latitude and Longitude. In the Latitude column, you set a random number formula that entered values between -90 and 90. In the Longitude column, you set a random number formula that entered values between -180 and 180. You created 25 random targets.
- Created the third button and code which loaded 25 random Target objects into the scenario.
- Created a fourth button and code which propagated a LEO Satellite in the scenario.
- Created a fifth button and code that computed access between the Satellite object and a Target object and imported the access times into *Excel*.
- Changed the fifth button code to format the access times to match the format in STK.
- Used the STK Excel Add-in to import selected LLA Data Provider Elements concerning the Satellite object into *Excel*.

Close Excel

1. Return to *Excel*.
2. Press Ctrl+S on your keyboard to save your workbook.
3. Close *Excel*. This will also close STK.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information concerning the STK Object Model and Connect. Now's a good time to go back through this tutorial and view that information. Obviously, there is a lot to learn. However, this tutorial should have provided some familiarization on how to use STK Programming Help. Explore!

You can try multiple tutorials to become more familiar with the STK Object Model and Connect: https://help.agi.com/stkdevkit/index.htm#automationTree/ADN.htm.

Part 14: Model Aircraft Missions with Aviator

Required Product Licenses: STK Premium (Air), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Note: This lesson requires STK 12.1 to complete it in its entirety. It includes new features introduced in STK 12.1.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- Aviator

Problem Statement

Aircrew mission planners require analytical tools that allow them to determine how atmospheric phenomena and terrain will affect the performance of an airborne mission. Furthermore, they need the ability to use the analytical tool to model real-world aircraft performance that accounts for variations in airframe performance characteristics and mission requirements. In this lesson, mission planners will fly a small commuter jet from Colorado Springs Municipal Airport to Telluride Regional airport. They will quickly add Navigational Aids as waypoints. They will determine how much fuel is required, and how much payload can be carried on board the aircraft in a fast, easy way.

Solution

- Use STK and STK's *Aviator* capability to design a cross country flight route.
- Use the *Aviator* Catalog Manager to:
    - Load airfield runway data into the scenario for takeoff and landing procedures.
    - Load Navigational Aids (NAVAIDs) to simulate physical devices on the ground that aircraft can detect and fly to.
- Use selected Data Providers to determine payload requirements and how much fuel is consumed during the flight.

What You Will Learn

Upon completion of this tutorial, you will understand the following:

- *Aviator* Catalog Manager
- *Aviator* Propagator
- *Aviator* Tools
- How to create Analytical Objects from the *Aviator* Catalog Manager and *Aviator*

Create a New Scenario

1. Launch STK ( ).
2. In the Welcome to STK window, click Create a Scenario.
3. Enter the following in the New Scenario Wizard:

Option	Value
Name:	STK_Aviator
Location:	Default
Start:	1 Aug 2020 18:00:00.000 UTCG
Stop:	+ 1 hr

4. When you finish, click OK.
5. When the scenario loads, click Save (). A folder with the same name as your scenario is created for you in the location specified above.
6. Verify the scenario name and location.
7. Click Save.

Note: Save Often!

Declutter the Labels

Your analysis will take place in very mountainous terrain which can obstruct object labels. Use Label Declutter to separate the labels on objects that are in close proximity for better identification in small areas.

1. Bring the 3D Graphics window to the front.
2. Open the 3D Graphics window properties ().
3. On the Details page, select Enable for Label Declutter.
4. Click OK to accept the changes, and close the Properties Browser.

Aviator Catalog Manager

***Aviator* provides a catalog structure** for the loading and saving of aircraft, airports, navaids, runways, VTOL points, and waypoints. Each of these mission elements has an associated catalog in STK. The ***Aviator* Catalog Manager** is a utility that allows you to view the contents of catalogs, create new items, copy or edit existing items, and search for specific items.

1. Extend the Utilities menu.
2. Select the *Aviator* Catalog Manager.
3. Expand Runway.
4. Select ARINC424 runways.
5. To the right, click the Use Master Data File ellipses (...).
6. Select My Computer.
7. Browse to C:\Program Files\AGI\STK 12\Data\Resources\stktraining\samples.
8. Select the FAANFD18 file.
9. Click Open.
10. On the *Aviator* Catalog Manager, click Save.
11. Keep the *Aviator* Catalog Manager open.

Determine the Length of a Runway

The aircraft will fly to and land at Telluride Regional Airport. Determine the length of the runway.

1. In the upper left corner of the *Aviator* Catalog Manager, enter Telluride in the Filter: field.

2. Click Enter.

3. Select TELLURIDE RGNL 09 27 in the list under ARINC424 runways.

> **Note:** When looking at runway data in the *Aviator* Catalog Manager, the two numbers next to the runway are reciprocal headings of the runway. 09 is 90 degrees (points east) and 27 is 270 degrees (points west). If there is more than one runway pointing in the same direction (parallel runways), each runway is identified by appending left (L), center (C) and right (R) to the number to identify its position (when facing its direction)–for example, runways one-five-left (15L), one-five-center (15C), and one-five-right (15R).

4. On the right, you will see data concerning the runway. Locate Length. The runway at Telluride Regional Airport is 7111 feet long.

Insert Analytical Objects from the Aviator Catalog Manager

A small commuter jet will takeoff from Colorado Springs Municipal Airport and land at Telluride Regional Airport. The Telluride Regional Airport runway sits on a plateau and dips slightly in the center which can provide a challenging landing for the pilot. Weather conditions in the area often rapidly change, and pilots must be aware of issues impacting the airfield such as high terrain which exceeds 14,000 feet as well as the runway's location on a plateau with a thousand-foot drop should the aircraft slide off of the runway. Use the *Aviator* Catalog Manager to insert the Colorado Springs Municipal Airport and the Telluride Regional Airport as Place ( ) objects into the scenario.

1. Under ARINC424 runways, right click on TELLURIDE RGNL 09 27.

2. Select Create STK Object from waypoint...

3. Change Type of object: to Place in the Create STK Objects window.

4. Change Color: if desired.

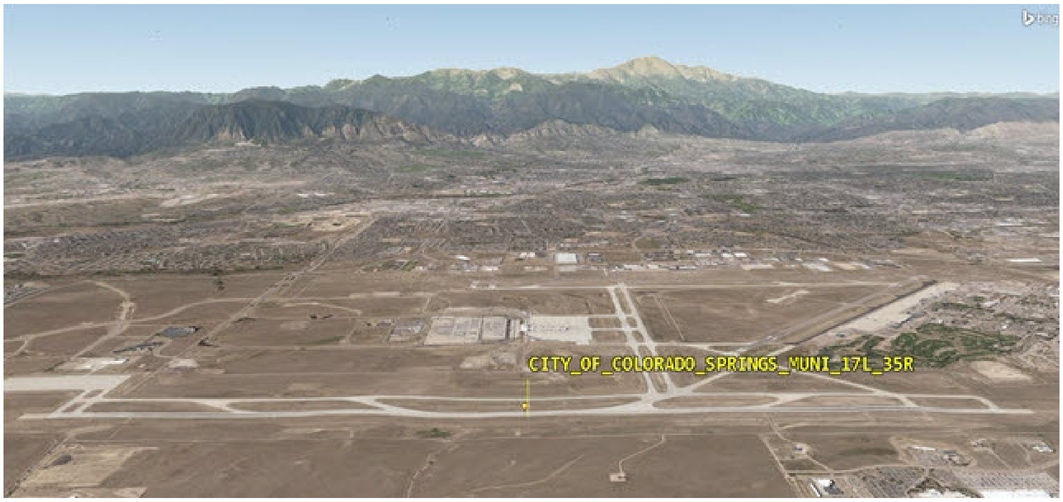
5. Click OK.

6. In the upper left hand side of the *Aviator* Catalog Manager, type Colorado Springs in the Filter: field.
7. Click Enter.
8. Right click on CITY OF COLORADO SPRINGS MUNI 17L 35R in the list under ARINC424 runways.
9. Select Create STK Object from waypoint.
10. Change Type of object: to Place in the Create STK Objects window.
11. Change Color: if desired.
12. Click OK.
13. When finished, close (✖) the *Aviator* Catalog Manager.

Situational Awareness

Now that you have the center points of both runways entered as Place ( ) objects, you can quickly zoom to them to view the runways and surrounding terrain features.

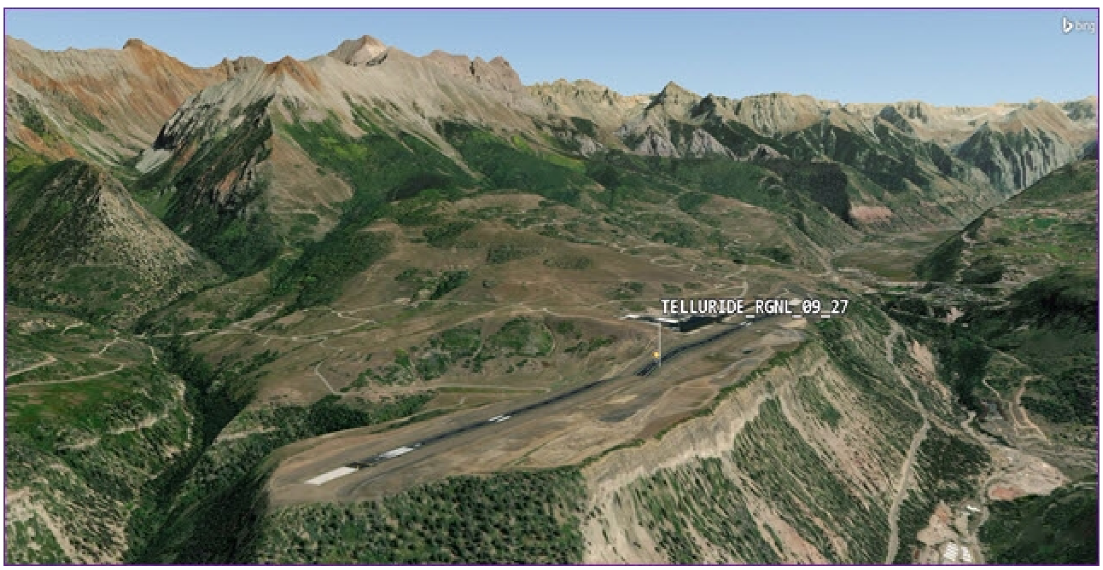
1. Bring the 3D Graphics window to the front.
2. Right click on CITY_OF_COLORADO_SPRINGS_MUNI_17L_35R in the Object Browser, and select Zoom To.
3. Use your mouse to change the view so that you can view the runway and its surroundings.



COLORADO SPRINGS RUNWAY AND SURROUNDINGS

4. Right click on TELLURIDE_RGNL_09_27 in the Object Browser, and select Zoom To.

5. Use your mouse to change the view so that you can view the runway and its surroundings.



TELLURIDE RUNWAY AND SURROUNDINGS

Insert An Aircraft

Insert an Aircraft ( ) object which you will use to create a flight plan.

1. Using the Insert STK Objects tool, insert an Aircraft ( ) object using the Insert Default ( ) method.
2. Rename the Aircraft ( ) object "Flight_Plan".
3. Open Flight_Plan's ( ) Properties ( ).

Aviator

Aviator provides an enhanced method for modeling aircraft - more accurate and more flexible than the standard Great Arc propagator. With *Aviator*, the aircraft's route is modeled by a sequence of curves parametrized by well-known performance characteristics of aircraft, including cruise airspeed, climb rate, roll rate, and bank angle. The precise state of an aircraft at any given time can be computed analytically - swiftly and without excessive data storage needs.

1. On the Basic - Route page, change the Propagator to Aviator.
2. Click Apply.
3. Click Optimize STK for *Aviator* on the Flight Path Warning pop up window. This also changes the animation time to X-Real Animation Time Mode.

   > **Note:** *Aviator* performs best in the 3D Graphics window when the surface reference of the globe is set to Mean Sea Level. You will receive a warning message when you apply changes or click OK to close the properties window of an *Aviator* object with the surface reference set to WGS84. It is highly recommended that you set the surface reference as indicated before working with *Aviator*.

4. Click OK to close the Fight Path Warning window.

Mission Window

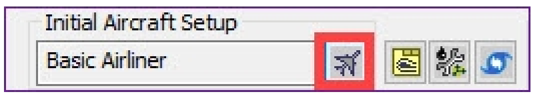
The **mission window** is used to define the aircraft's route when *Aviator* has been selected as the propagator. The mission window contains **three toolbars** - Initial Aircraft Setup, Phases of Flight, and Procedures and Sites -

that enable you to define the aircraft that you are modeling and to create, modify, and delete phases and procedures. The **mission list** provides an overview of the mission by listing each of the mission phases and the procedures within them, in the order in which they will be executed. The **mission profile** can display a variety of data describing the mission.

Initial Aircraft Setup - Select Aircraft

The buttons on the Initial Aircraft Setup toolbar are used to define the aircraft model that will be used in the mission. The basic models found in Select Aircraft window are representative of an aircraft type, but not a specific aircraft. It's up to you to customize the model you choose to match actual aircraft characteristics. This is an introduction to *Aviator* so you will make some minor changes.

1. In the Initial Aircraft Setup toolbar, click Select Aircraft.



INITIAL AIRCRAFT SETUP TOOLBAR - SELECT AIRCRAFT

2. Right click on Basic Business Jet, and select Duplicate.

3. Right click on Basic Business Jet Copy, and select Rename.

4. Rename Basic Business Jet Copy to FlightPlan.

5. Ensure FlightPlan is selected, and click OK.

Initial Aircraft Setup - Aircraft Properties

Aircraft Properties provide access to **performance models**. Performance models are used to define the behavior of the aircraft in flight. By specifying performance models to use with each phase of the mission, you can vary the manner in which the aircraft performs based on the priorities of the mission. You'll use default settings mostly.

1. In the Initial Aircraft Setup toolbar, click Aircraft Properties ( ).

Acceleration Performance Model

The **Basic Acceleration performance model** is comprised of three tabs:

- Basic: define the basic turning, climb and descent transition, and attitude characteristics of the aircraft
- Aerodynamics: select and define strategies to model attitude characteristics
- Propulsion: select and define strategies to model propulsion characteristics

You want to determine how much fuel is consumed during the flight.

1. Select the Acceleration Built-In Model in the Performance Models section.
2. Ensure the Basic tab is selected.
3. In the Level Turns section, open the pull down menu and select Scale by atmosphere density.
4. In the Climb and Descent Transitions section, select Scale by atmosphere density in the drop down menu.
5. Select the Aerodynamics tab.
6. Change the Strategy: to Basic Fixed Wing.
7. Select the Propulsion tab.
8. Change the Strategy: to Basic Fixed Wing.
9. Click Save.

Notice that the Mode: is set to Jet - Specify Net Thrust. You will use the default values for both aerodynamics and propulsion, but they will have an affect on fuel consumed. All of this data would be changed according to the actual specifications of your aircraft.

Climb Performance Model

The **Basic Climb performance model** is comprised of a simple set of parameters that define the flight characteristics of the aircraft while climbing.

1. Select the Climb Built-In Model in the Performance Models section.
2. Select Use Aero/Propulsion Fuel Flow.
3. Click Save.

Cruise Performance Model

The **Basic Cruise performance model** is comprised of a simple set of parameters that define the flight characteristics of the aircraft during level flight. Since this is a fairly short flight, the aircraft will climb to 25000 feet and level off.

1. Select the Cruise Built-In Model in the Performance Models section.
2. Change the Default Cruise Altitude: to 25000 ft.
3. Select Use Aero/Propulsion Fuel Flow.
4. Click Save.

Descent Performance Model

The **Basic Descent performance model** is comprised of a simple set of parameters that define the flight characteristics of the aircraft while descending.

1. Select the Descent Built-In Model in the Performance Models section.
2. Enable Use Aero/Propulsion Fuel Flow.
3. Click Save.

Landing Performance Model

The **Basic Landing performance model** is comprised of a simple set of parameters that define the flight characteristics of the aircraft during a landing.

1. Select the Landing Built-In Model in the Performance Models section.
2. Enable Use Aero/Propulsion Fuel Flow.
3. Click Save.

Takeoff Performance Model

The **Basic Takeoff performance model** is comprised of a simple set of parameters that define the flight characteristics of the aircraft during a takeoff.

1. Select the Takeoff Built-In Model in the Performance Models section.
2. Enable Use Aero/Propulsion Fuel Flow.
3. Click Save.
4. Click Close.
5. Click Apply to apply changes, and keep the Properties Browser open.

Initial Aircraft Setup - Configuration

The Configuration window is used to define the aircraft's fuel and payload configuration.

1. In the Initial Aircraft Setup toolbar, click **Configuration** ( ).
2. Change the Empty Weight: value to 31000 lb. This is where you add payload weight. This will account for the pilot, instructor, and baggage.

3. Note the Max Landing Weight value. If, at the end of the analysis, the Aircraft ( ) object weighs more than this value, a warning will appear in Message Viewer.

4. Note the Total Weight value. This is the empty weight and the fuel load of the Aircraft ( ) object.

5. Select the Stations tab.

6. Click Internal Fuel.

7. Note the Capacity and Initial state values. After your initial analysis, you may need to adjust the initial state.

8. Click OK.

9. Click Apply to apply changes, and keep the Properties Browser open.

Initial Aircraft Setup - Mission Wind Model

Use the Wind and Atmosphere Model tool to simulate wind and atmospheric conditions for the scenario, a mission, a specific procedure, or a group of selected procedures.

1. In the Initial Aircraft Setup toolbar, click Mission Wind Model ( ).

> **Note:** For the purposes of this scenario you will use a constant bearing and speed for your wind. If you were mission planning on the current day, you would want to consider using the NOAA ADDS Service model. The NOAA ADDS Service wind model allows you to use forecasts from the Aviation Digital Data Service (ADDS), provided by the National Oceanic and Atmospheric Administration (NOAA), to define the wind effect.

2. Change the Wind Bearing: value to 180 deg.

3. Change the Wind Speed: value to 20 nm/hr.

4. Click OK.

5. Click Apply to apply changes, and keep the Properties Browser open.

Flight Plan

In this scenario, you will use one **phase**. You can have multiple phases, if you desire. Each phase can contain a separate performance model for the Aircraft ( ). The aircraft will takeoff from Colorado Springs Municipal Airport and fly direct to Blue Mesa VOR/DME. A VOR/DME is a radio beacon that combines a VHF omnidirectional range (VOR) with a distance measuring equipment (DME). Turning at Blue Mesa VOR/DME, the aircraft will fly to Cones VOR/DME, and begin its final approach and land at Telluride Regional Airport.

Site Properties - Select Runway

If you have ARINC424 airport data available in the *Aviator* Catalog Manager, you can define a site using an airport in that data.

1. In the Mission List window, right click on Phase 1 and select Insert First Procedure for Phase ( ).
2. Select Runway from Catalog ( ) in the Site Properties / Select Site Type: section.
3. Enter Colorado Springs in the Filter: field.
4. Click Enter.
5. Under ARINC424 runways, select CITY OF COLORADO SPRINGS MUNI 17L 35R.
6. Click Next.

Procedure Properties - Takeoff

A **Takeoff** procedure launches an aircraft from a runway site into the air.

1. Select Takeoff ( ) in the Procedure Properties window / Select Procedure Type: section.
2. Set the following:

Option	Value
Name:	COS Runway
Use runway heading 172 Mag 180 True (Headwind)	enabled
Runway Altitude Offset:	7 ft
Use Terrain for Runway Altitude	enabled

3. Click Finish.
4. Click Apply to apply changes, and keep the Properties Browser open.

Site Properties - End of Previous Procedure

The end of the previous procedure can be used as a waypoint to define the site of the next procedure. In this instance, due to terrain, you want to gain altitude prior to flying to Blue Mesa VOR/DME.

1. Right click on CITY OF COLORADO SPRINGS MUNI 17L 35R in the Mission List, and select Insert Procedure After ( ).
2. Select End of Previous Procedure ( ) in the Site Properties window / Select Site Type: section.
3. Change the Name: to Climb.
4. Click Next.

Procedure Properties - Basic Maneuver Climb Before Turning

A **Basic Maneuver** procedure is a single action undertaken by the aircraft. It is unlike most procedures in *Aviator*, which represent sets of actions that together comprise a common flying procedure.

1. Select Basic Maneuver ( ) in the Procedure Properties window / Select Procedure Type: section.
2. Change the Name: to Straight 20 nm.

3. In the Horizontal / Navigation tab settings, note that the strategy: is set to Straight ahead. Open the pull down menu to view other strategies.

4. Set the following :

Option	Value
Strategy:	Straight Ahead (default)
Basic Stop Conditions - Time of Flight:	disable
Basic Stop Conditions - Downrange:	20 nm

5. Select the Vertical / Profile tab.

6. Set the Altitude - Mode: to Specify Altitude Change.

7. Set the Altitude - Relative Altitude Change: value to 10000 ft.

8. Click Finish two times.

9. Click Apply to apply changes, and keep the Properties Browser open.

Site Properties - Navaid Fly to Blue Mesa

If you have ARINC424 navaid data available in the *Aviator* Catalog Manager, you can define a site using a navaid from that data.

1. Right click on Climb in the Mission List, and select Insert Procedure After ().

2. Select Navaid from Catalog () in the Site Properties window / Select Site Type: section.

3. Enter HBU in the Filter: field. HBU is the FAA designator for Blue Mesa VOR/DME.

4. Click Enter.

5. Right click on HBU, and select Create STK Object from waypoint...

6. Set Type of object: to Place.

7. Change the Color: if desired.

8. Click OK.

9. Click Next.

Procedure Properties - Basic Point to Point

A **Basic Point to Point** procedure is a basic traverse between two waypoints.

1. Select Basic Point to Point ( ) in the Procedure Properties window / Select Procedure Type: section.

2. Set the following:

Option	Value
Name:	Blue Mesa
Navigation Options - Nav Mode:	Fly Direct
Enroute Options - Turn Factor	5.00 (less roll)

3. Click Finish.

4. Click Apply to apply changes and keep the Properties Browser open.

Site Properties - Navaid Fly to Cones

1. Right click on HBU in the Mission List, and select Insert Procedure After ( ).

2. Select Navaid from Catalog ( ) in the Site Properties window / Select Site Type: section.

3. Enter ETL in the Filter: field.

4. Click Enter.

5. Right click on ETL, and select Create STK Object from waypoint...

6. Set Type of object: to Place.

7. Change the Color: if desired.

8. Click OK.

9. Click Next.

Procedure Properties - Basic Point to Point

1. Select Basic Point to Point ( ) in the Procedure Properties window / Select Procedure Type: section.

2. Set the following:

Option	Value
Name:	Cones
Altitude - Use Aircraft Default Cruise Altitude	clear
Altitude - Altitude:	15000 ft
Enroute Options - Turn Factor	5.00
Enroute Cruise Airspeed - Pull-down menu	Other Airspeed
Enroute Cruise Airspeed - Airspeed:	250 nm/hr

3. Click Finish.

4. Click Apply to apply changes and keep the Properties Browser open.

Site Properties - Select Runway

1. Right click on ETL in the Mission List, and select Insert Procedure After ( ).

2. Select Runway from Catalog ( ) in the Site Properties / Select Site Type: section.

3. Enter Telluride in the Filter: field.

4. Click Enter.

5. Select TELLURIDE RGNL 09 27 under ARINC424 runways.

6. Click Next.

Procedure Properties - Landing

A **Landing** procedure brings an aircraft down from the air to a runway site.

1. Select Landing ( ) in the Procedure Properties window / Select Procedure Type: section.

2. Set the following:

Option	Value
Name:	Telluride Runway
Approach Mode:	Intercept Glideslope
Use runway heading 096 Mag 105 True (Headwind)	selected
Runway Altitude Offset:	7 ft
Use Terrain for Runway Altitude	selected

3. Click Finish.

4. Click Apply to apply changes and leave the Properties Browser open.

Message Viewer

STK uses the **Message Viewer** window to display error messages, warning messages, and informational messages. Currently, there is a warning in Message Viewer.

1. In the STK Menu area, open the View menu and select Message Viewer. Look at the last message. Expand as necessary. The maximum landing weight for the aircraft is 40000 pounds. It is to heavy.

MESSAGE VIEWER WARNING

2. At the bottom of Message Viewer, you'll see a tab named All Messages. Right click on the All Messages tab and select Clear All Tabs.

3. Close (✖) the Message Viewer.

Flight Profile by Time Custom Report

The data provider **Flight Profile By Time** has the elements required for your analysis. Flight data is sampled using a constant time step between grid points. This report style is only available for *Aviator* propagated vehicles.

1. In the Object Browser, right click on Flight_Plan ( ), and select the Report & Graph Manager.

2. In the Styles list, right click on the Flight Profile by Time report and select Properties.

3. In the Report Contents list, select Flight Profile By Time-Fuel Consumed. This opens the Flight Profile By Time Data Provider on the left.

4. In the Flight Profile By Time Data Provider, move ( ) Fuel State and Weight elements to the Report Contents list.

5. Click OK.

6. Click OK to close the Warning.

7. In the Styles list, expand the My Styles folder.

8. Right click the Flight Profile by Time report in the My Styles folder, and select Rename.

9. Rename the report "My Flight Profile by Time".

10. Click Generate

```
Fuel Consumed (lb)   Fuel State (lb)    Weight (lb)
------------------   ---------------    -----------
             0.000         20000.000      51000.000 (Prior to Takeoff in Colorado Springs)
          7761.778         12238.222      43238.222 (The moment the plane touches the runway in Telluride)
```

FIRST AND LAST LINES OF FLIGHT PROFILE BY TIME REPORT

Focusing on fuel consumed, fuel state and the weight of the aircraft, you can see that the plane is approximately 3238 pounds above its maximum landing weight of 40000 lbs when it touches down. You landed with approximately 12238 pounds of fuel.

11. Leave the My Flight Profile by Time report open.

Adjust the Initial Fuel State

You have the option of adjusting the initial fuel state and payload. In this instance, adjust the initial fuel state. Keep in mind you want reserve fuel. You landed with approximately 12238 pounds of fuel. Remove 6000 pounds of fuel.

1. Return to Flight_Plan's ( ) Properties ( ).
2. In the Initial Aircraft Setup toolbar, click Configuration ( ).
3. Select the Stations tab in the Aircraft Configuration window.
4. Select Internal Fuel.
5. Change the Initial state: value to 14000 lb.
6. Click Apply.
7. Click OK.
8. Click OK to close Flight_Plan's ( ) Properties Browser.

Refresh the My Flight Profile by Time Report

1. Bring the My Flight Profile by Time report to the front.

2. Refresh ( ) the report.

```
Fuel Consumed (lb)    Fuel State (lb)    Weight (lb)
------------------    ---------------    -----------
             0.000          14000.000      45000.000 (Prior to Takeoff in Colorado Springs)
          7613.889           6386.111      37386.111 (The moment the plane touches the runway in Telluride)
```

ADJUSTED FLIGHT PROFILE BY TIME

Focusing on fuel consumed, fuel state and the weight of the aircraft, you can see that the plane is approximately 2614 pounds below its maximum landing weight. You landed with plenty of reserve fuel. Furthermore, you needed less fuel to arrive at your destination.

3. Look at Message Viewer. Due to adjusting the weight of the aircraft, there are no new warnings.

4. When finished, close ( ) the report and the Report & Graph Manager.

5. Close ( ) the Message Viewer.

2D Graphics Window Flight Route View

Use the 2D Graphics window to get a good view of the flight route.

1. Bring the 2D Graphics window to the front.

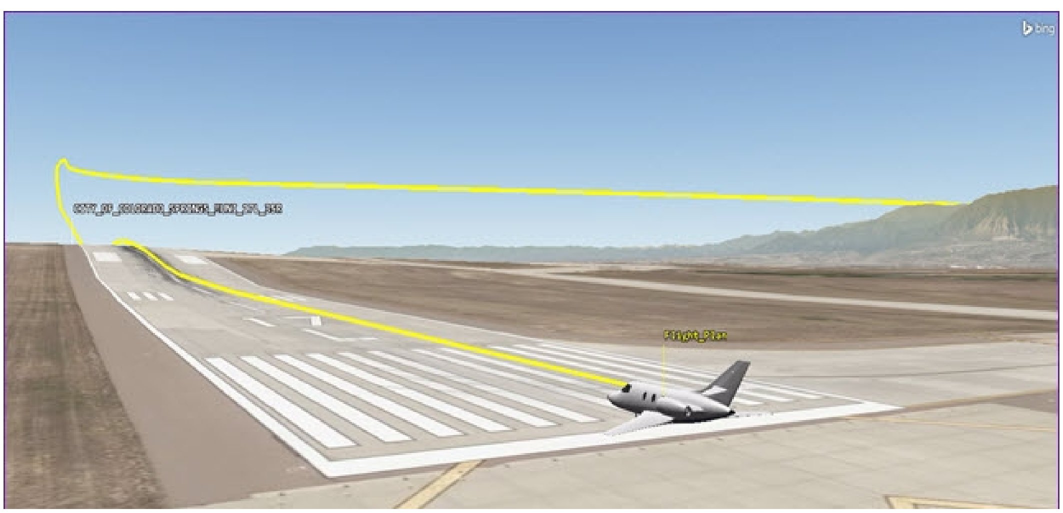
2. Zoom in until you can see the flight route

2D GRAPHICS WINDOW VIEW OF THE FLIGHT ROUTE

View the Flight

Use the 3D Graphics window to observe the mission.

1. Bring the 3D Graphics window to the front.
2. Reset ( ) the scenario.
3. Zoom To Flight_Plan.



4. Adjust (,) the time step as desired.

5. Start ( ) the scenario.

6. When finished, Reset ( ) the scenario.

7. You can Zoom To ETL and HBU to view the actual VOR/DME ground transmitter sites.

Save Your Work

1. Save ( ) your work.

Summary

You began by loading and saving of aircraft, airports, navaids, runways, VTOL points, and waypoints using the Aviator Catalog Manager. Using *Aviator*, you mission planned for a small commuter jet taking off from Colorado Springs Municipal Airport and landing at Telluride Regional Airport. During the initial aircraft configuration, you added 1000 pounds to the aircraft to account for increased payload. You tweaked performance models to determine how much fuel was required for the flight. The wind bearing for the entire mission was out of the south at 20 miles per hour. After takeoff, you flew straight ahead to gain altitude due to mountainous terrain. After 20 miles, you turned and flew direct to Blue Mesa VOR/DME. Making a slight turn, you continued to Cones VOR/DME. You were able to line up the aircraft by arriving at Cones with a heading taking you directly to Telluride. After landing in Telluride, you viewed a warning in Message Viewer that informed you of the aircraft's weight being over the maximum allowed weight of 40,000 pounds. You then used a customized Flight Profile by Time report to determine how much the aircraft weighed during landing and how much fuel you still had on board. Returning to the aircraft configuration settings, you adjusted the initial fuel load. Re-analyzing the mission, you were able to land in Telluride under the maximum allowable weight limit with plenty of reserve fuel.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information of various tools and functions. Now's a good time to go back through this tutorial and view that information. You can continue to adjust performance models and reanalyze the mission. Use a different aircraft model, and try different procedure types. In this scenario, you flew straight ahead for 20 nautical miles. Try some barrel rolls or loops. Have some fun.

Part 15: Introduction to the Advanced CAT Tool

Required Product Licenses: STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro
- Conjunction Analysis Tool

Problem statement

Engineers and operators need to easily address situations in which the launch or operation of a satellite or system of satellites, or a related Earth-based operation, may be affected by the actual or apparent proximity of other orbiting objects. Such effects range from a temporary delay or loss of access to the system to physical damage of space-based assets. In this scenario, you want to analyze seven days of data to determine the probability of your satellite having a conjunction with any other satellites or debris.

Solution

Use the Advanced Conjunction Analysis Tool (AdvCAT), which is a part of the STK's *Conjunction Analysis* capability, to carry out a close-approach analysis between a primary object (your satellite) and secondary objects (satellites possibly presenting a risk of collision). A conjunction occurs when two orbiting objects are closer than the specified minimum acceptable distance. You choose whether the distance is measured between the ellipsoidal threat volumes of the objects or by the range between the objects. In this scenario, you will complete a linear analysis using two-line element sets (TLEs) .

What you will learn

After completing this tutorial, you will understand how to use AdvCAT to determine conjunctions of orbiting objects.

Video Guidance

Create a new scenario

1. Launch STK ( ).
2. In the Welcome to STK window, click **Create a Scenario**.
3. Enter the following in the STK: New Scenario Wizard:

Option	Value

Name:	STK_CAT
Location:	Default
Start:	1 Nov 2020 17:00:00.000
Stop:	+ 7 days

4. When you finish, click **OK** .
5. When the scenario loads, click Save (). STK creates a folder with the same name as your scenario and places it in the location specified above.
6. Verify the scenario name and location and click **Save** .

Note: Save often as you progress through the scenario!

Prepare STK

For this scenario, you will not use the Timeline View nor the 2D Graphics window. Close them.

1. Close the Timeline View at the bottom of the STK window.
2. Close the 2D Graphics window.
3. Maximize the 3D Graphics window.

Obtain an archived satellite database

AdvCAT does not add any objects to the scenario. It merely propagates ephemerides for the primary and secondary objects that you select for the specified time frame. Use a local database for the analysis.

With AdvCAT, you can use either satellite objects propagated from your TLE database or analytical objects downloaded and propagated from the AGI server .

1. Select the scenario STK_CAT () and click properties ().
2. In the properties window, select the Basic - Database page.
3. Click **Update Database Files**.
4. When the Update Satellite Database window opens, set the following:

Option	Value
Option	Obtain Archived Database
Database Information	Specific Database: stkAllTLE
Database	Scenario Location (typically C:\Users\username\Documents\STK 12\STK_CAT)
Archive Date:	1 Nov 2020 17:00:00.000 UTCG

5. Click Update .
6. Click OK to close the Information window.
7. In the Update Satellite Database window, click Close .
8. Click OK to close STK_CAT's properties.

Primary satellite

The primary satellite used in the analysis is your satellite. For this scenario, your satellite is STARLINK-1611.

> **Note:** If you have your own ephemerides converted to *.e files, regardless of the reference frame, STK will handle all the conversions internally for whatever analysis needs to be performed. When using the AdvCAT, STK needs *.e files, manually entered satellite properties, or TLE sets to run *CAT*. Any reference frame is acceptable.

1. Using the Insert STK Objects tool ( ), insert a Satellite ( ) object using the From TLE File method.
2. When the Select a TLE File window opens, browse to the location of the downloaded TLE file named stkAllTLE.tce, typically C:\Users\username\Documents\STK 12\STK_CAT.
3. Select stkAllTLE.tce.
4. Click **Open**.
5. When the Question window opens, read the data and click **OK** or **Yes**. Be patient, as this can take a minute or two to load.

Modify the Satellite Database options

1. When the Insert From Satellite Database window opens, click **Modify**.
2. When the Satellite Database: TLE Source window opens, clear the **On propagation, automatically retrieve elements** checkbox.
3. Click **OK**.
4. When the Question pop up opens, click **OK** or **Yes**.
5. When the Insert From Satellite Database window repopulates, enter 46147 in the SSC Number field.
6. Click **Search**.
7. In the Results list, select STARLINK-1611.
8. Click **Insert**.
9. After STARLINK-1611 ( ) has propagated, click **Close**.

Add the AdvCAT Object to the Insert STK Objects tool

1. Bring the Insert STK Objects tool () to the front.
2. Click **Edit Preferences** .
3. In the New Object list, select AdvCAT ().
4. Click **OK** .

Create an Advanced CAT object

The object () provides a convenient way for you to carry out close-approach analyses for multiple satellites and TLEs.

1. Using the Insert STK Objects tool (), insert an AdvCAT () object using the Insert Default method.
2. Open AdvCAT1's properties ().

Selecting and defining analysis objects

Most of the Main page of the AdvCAT Properties is comprised of two lists: a Primary List and a Secondary List. The Primary List contains satellites of interest to you, such as those that you own or wish to use. The Secondary List contains satellites that present a potential risk of collision with, or unacceptably close approach to, satellites in the Primary List.

Analysis object attributes - primary satellite

In analyzing close approaches between a primary and secondary object, AdvCAT assigns to each a threat volume comprising an ellipsoidal shape enclosing the object. The following are key Analysis Object attributes:

- Fixed class specifies the dimensions of the threat volume ellipsoid.
- Tangential is the dimension of the threat volume ellipsoid along the X axis.
- Cross Track is the dimension of the threat volume ellipsoid along the Y axis.
- Normal is the dimension of the threat volume ellipsoid along the Z axis.

Since you're evaluating potential linear conjunctions and not using covariance settings, keep the default Class, Tangential, CrossTrack, and Normal values. Actual threat volumes would be set based on established ellipsoid and covariance screenings.

1. In the Main page of the AdvCAT Properties, go to the Primary List and move ( ) Satellite/STARLINK-1611_46147 to the Chosen: list.

Chosen:

Name	Class	Tangential	CrossTrack	Normal	Type	HardBodyRadius	NumberID	StringID
Satellite/STARLINK-1611_46147	Fixed	20 km	10 km	5 km	Scenario Object	0.001 km	0	

2. Use a typical Hard Body Radius of an A-Train satellite. Set the HardBodyRadius value to 3.0 m.
3. Click **Apply** .

Analysis Object attributes - secondary satellites

The U.S. Strategic Command (USSTRATCOM) keeps track of thousands of space objects. These objects constitute the space object catalog. While most of the catalog is made available to the public, some information is restricted. AGI provides the publicly released information for use with STK in the form of satellite database files and TLEs. AGI updates this data at least once and up to three times a day. Your analysis will check for potential conjunctions between STARLINK-1611 and the complete satellite database.

1. In the Secondary List, move (→) stkAllTLE.tce to the Chosen: list.
2. Set the HardBodyRadius value to 2.0 m.
3. Click Apply .

Threshold

Often, the threat volume represents the degree of uncertainty about an object's position at any given time. AdvCAT computes the range between the threat volumes of the two objects at specified time steps over a given interval. It gives a warning whenever the range falls below a user-selected threshold. A collision event occurs whenever the range between the two threat volumes becomes zero or negative.

At the top of the Basic - Main page, note the Threshold: value of 10 km. This can be changed manually when required.

Using prefilters

The basic idea behind close-approach processing is to start with all cataloged orbiting objects and then efficiently delete the members of the population that do not come within the specified distance of the reference object. The first step is eliminating as many members of the population as possible via geometric properties, which takes considerably less time than fully propagating these satellites and then computing close approaches. The final determination of the existence of close approaches is always done by sampling the ephemeris of the candidate and reference objects, but some **prefilters** are usually applied to limit the amount of ephemeris generation that is required.

1. In the AdvCAT Properties, select the Basic - Advanced page.
2. Note the selected Pre-Filters and their values.
   - Apogee / Perigee: AdvCAT uses the apogee/perigee prefilter to cut candidate close-approach objects having a range of altitude that does not overlap with that of the reference object.

- Time: The goal of the time filter is to identify time intervals when each object in a pairing is close enough to the elliptical representation of the other object's trajectory to have a conjunction.

Compute possible conjunctions

When you compute possible conjunctions, any object threat volumes that fall within the threshold and prefilter distances appear as ellipsoids in the 3D Graphics window after creating a report.

1. In the AdvCAT properties, select the Basic - Main page.
2. Select the **Display Acknowledgment when done** checkbox.
3. Click Compute . Be patient. This could take a minute. There is a progress bar visible in the lower right corner of STK.
4. When the Advanced CAT message window appears, read the message and then click OK .

Close approach by minimum range report

Right now, you're interested in a few specific data providers. Remember, AdvCAT only reports objects with threat volumes that come within ten (10) kilometers and also pass the prefilters of your primary satellite.

1. In the Object Browser, right-click AdvCAT1 ( ) and select **Report & Graph Manager**.
2. In the Styles section, in the Installed Styles folder, select **Close Approach By Min Range**.
3. Click Generate .
4. Look through the report and focus on Object Name, Time In (UTCG), Time Out (UTCG), Min Separation (km) and Min Range (km). The AdvCAT Data Provider is Events by Min Range. The following are the data provider elements used in the report:

- Object Name: This is the name of the secondary object involved in the close-approach event.
- Time In: This is the start time of the event. For this scenario, it is when the threat volume is within 10 kilometers of the primary's threat volume.
- Time Out: This is the stop time of the event. For this scenario, it is when the threat volume moves beyond 10 kilometers of the primary's threat volume.
- Min Separation: This is the separation distance between the primary and secondary threat volumes at the time of closest approach. If the ellipsoids intersect, then the value will be "Intersect".
- Min Range: This is the distance between the center points of the primary and secondary objects at the time of closest approach.

5. When finished, close the report.

Create a custom report

Add three more **Events by Min Range** elements to your report. This will add situational awareness.

1. In the Installed Styles section, right-click **Close Approach By Min Range** and select Properties ( ).
2. In the Report Style window, under Report Contents, select a value in Section 6.
3. Under Data Providers, expand (⊞) the Events by Min Range folder.
4. Move ( ) **Time of Close Appr** (TCA) to the Report Contents list.
5. Move ( ) **Relative Velocity** to the Report Contents list.
6. Move ( ) **Collision Probability** (Analytic) to the Report Contents list.
7. Click OK .
8. Read the Warning message and then click OK .

This added new elements to the custom report:

- Time of Close Appr (TCA): This is the time when the minimum range occurs between the primary and secondary bodies.
- Relative Velocity: This is the magnitude of the difference in the inertial velocities of the primary and secondary objects at a given time.
- Collision Probability (Analytic): This is the probability of collision computed using an analytic method derived from the book *Spacecraft Collision Probability* by F. Kenneth Chan.

Rename and run the report

1. In the Styles section, expand (⊞) the My Styles folder.
2. Rename the custom report to be "My Close Approach By Min Range".
3. Click **Generate** .
4. Look through the report.

Identify and insert a close approach

Focus on the first satellite in the report.

1. In the report, copy the SSC number (Satellite Catalog Number) of the first satellite in the report, for example 45540.
2. Using the Insert STK Objects tool (), insert a Satellite ( ) object using the From TLE File method.
3. When the Select a TLE File window opens, browse to the location of the downloaded TLE file named stkAllTLE.tce, which is typically C:\Users\username\Documents\STK 12\STK_CAT.
4. Select stkAllTLE.tce.
5. Click **Open** .

6. When the Question pop up opens, read the data and click OK or Yes . Be patient, this can take a minute or two to load.

Modify the Satellite Database options

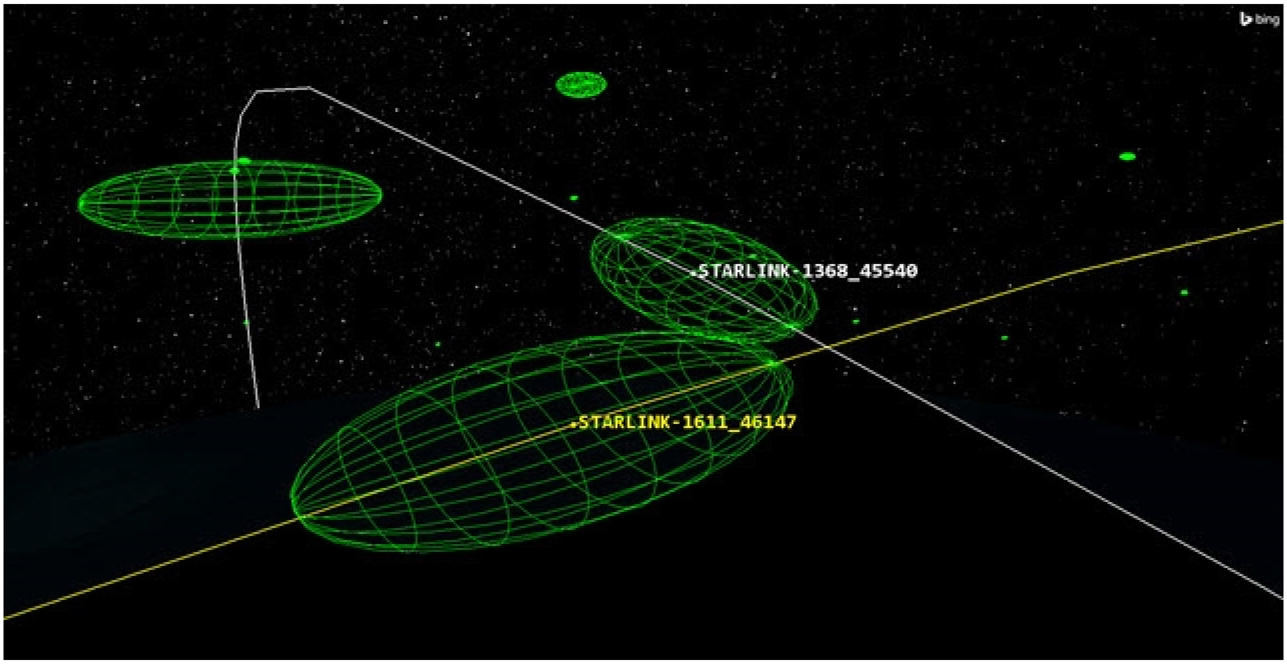
1. When the Insert From Satellite Database window opens, click Modify .
2. When the Satellite Database: TLE Source window opens, clear **On propagation, automatically retrieve elements**.
3. Click OK .
4. When the Question window opens, click OK or Yes .
5. When the Insert From Satellite Database window repopulates, paste or type in the first satellite's SSC number from the report into SSC Number field, for example 45540.
6. Click Search .
7. In the Results list, select the satellite, for example STARLINK-1368.
8. Click Insert .
9. After the Satellite ( ) object has propagated, click Close .

Visualize the close approach

1. In the report, right-click on the first Time In (UTCG), select Time In, and then select Set Animation Time.
2. Bring the 3D Graphics window to the front.
3. Right-click on STARLINK-1611_46147 ( ) and select Zoom To.
4. In the Animation Tool Bar, click Decrease Time Step ( ) until your Time Step: value is 0.01 sec.

5. Click Step in Reverse ( ) one time.

6. Using your mouse, zoom out until you can see the primary and secondary ellipsoids.



All of your ellipsoids are green. When they enter the threshold of 10 kilometers, they turn yellow. When they intersect, they turn red. Other satellites that enter the threshold are represented by ellipsoids. They aren't analytical objects.

7. Click Start ( ) to animate the scenario.

8. Run the animation through the conjunction. After the conjunction, when the two satellites turn green again, click Pause ( ).

Set the animation time to the Time of Close Approach

1. Return to the report.
2. Set the animation time to the Time of Close Appr (UTCG) of the two satellites.
3. Return to the 3D Graphics window.
4. Using your mouse, zoom in so that you can get a good view of both satellites.

5. When finished, Reset ( ) the scenario.

6. In the 3D Graphics window, click Home View ( ).

7. Close the report and the Report & Graph Manager.

Visualize all the satellites

At this time, only the satellites having threat volumes that fell within the 10 kilometer threshold and passing the prefilters are visible in the 3D Graphics window. You can display all secondary ellipsoids if desired.

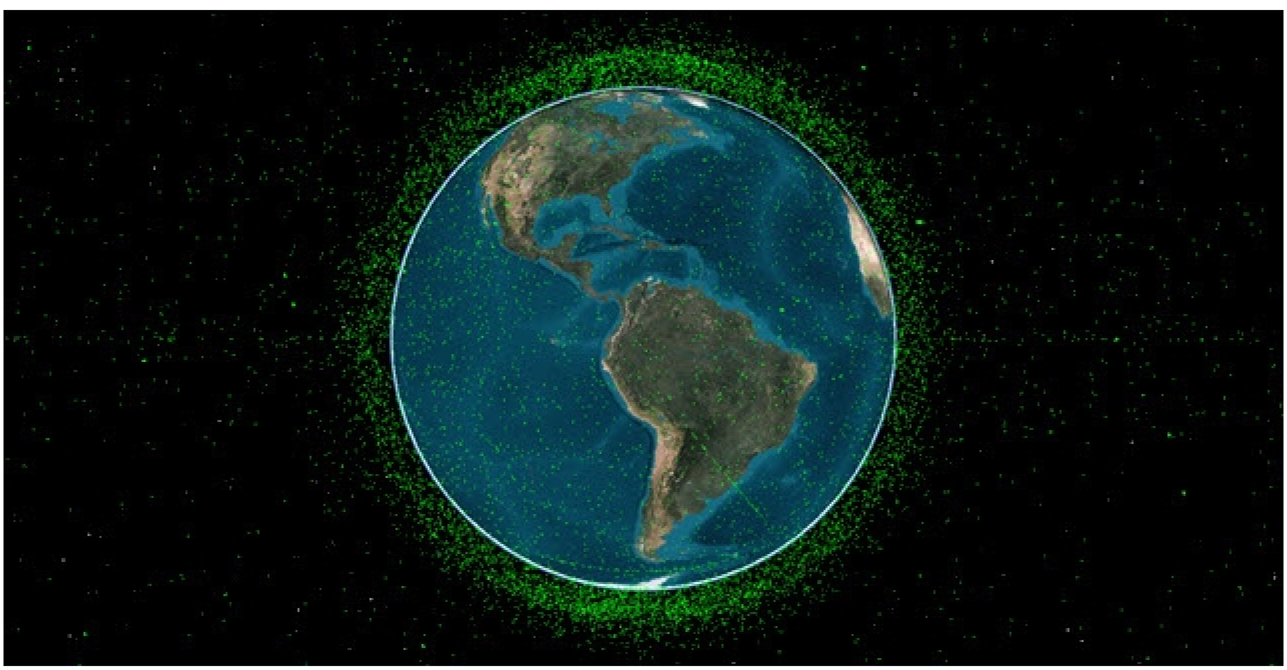
1. Return to AdvCAT1's ( ) properties ( ).

2. Select the 3D Graphics - Attributes page.

3. In the Visibility section are the primary ellipsoid and secondary ellipsoids that have conjunctions. Enable All.

4. Click OK .

5. In the Object Browser, uncheck both Satellite ( ) objects.



6. In the Animation Tool Bar, click Increase Time Step () until your Time Step: value is 10.00 sec.
7. Click Start ( ) to animate the scenario. Remember, the satellites are represented by ellipsoids that are 20 by 10 by 5 kilometers in size!
8. Use your mouse to zoom out until you see the geostationary belt.

Save your work

1. When you're finished, Reset () the scenario.
2. Save () your work.

Summary

You began by updating your satellite database with an archived database of satellites that matched your scenario time period. Next, you inserted the primary satellite into the scenario. After inserting the AdvCAT object, you moved the primary satellite from the Primary List to the Chosen list. Then you moved the complete satellite database (stkAllTLE.tce) from the Secondary List to the Chosen list. You left the threat volumes and threshold at default values, and then launched the close approach computation process. Using the Events by Time In data provider and elements, you created a custom report that allowed you to view important information concerning possible conjunctions with your primary satellite. You ended by visualizing a close approach and by visualizing all the satellite ellipsoids from the stkAllTLE.tce database.

On your own

Throughout the tutorial are hyperlinks that point to in-depth information concerning the AdvCAT. Now is a good time to go back through this tutorial and view that information. Experiment with other satellites, data providers, and prefilters. Explore and have fun!

If you're interested in a more in-depth tutorial that uses covariance data and performs a nonlinear conjunction analysis, try the **Advanced CAT Tool: Assessing the Threat of a Collision** tutorial

Part 16: Design Trajectories with Astrogator

Required Product Licenses: STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities Covered

This lesson covers the following STK Capabilities:

- STK Pro
- Astrogator

Problem

Engineers and operators require a quick way to design high-fidelity spacecraft trajectories for mission planning and operations. In this scenario, they will design a launch from a launch pad, and successfully inject a satellite into a geosynchronous equatorial orbit (GEO).

Solution

Use STK's *Astrogator* capability to design:

1. A basic launch phase to place a satellite into a parking orbit (low Earth orbit or LEO)
2. A transfer orbit injection (TOI) maneuver to transfer from LEO to GEO

3. A synchronized orbit injection (SOI) maneuver to circularize the orbit at GEO

What You Will Learn

Upon completion of this tutorial, you will have a basic understanding of:

- *Astrogator*
- The Launch Vehicle Object

Video Guidance

Create a New Scenario

Create a new scenario.

1. Launch STK ( ).
2. In the Welcome to STK window, click Create a Scenario.
3. Enter the following in the New Scenario Wizard:

Option	Value
Name:	STK_Astrogator
Location:	Default
Start:	Default
Stop:	+ 5 days

4. When finished, click OK .

5. When the scenario loads, click Save (). A folder with the same name as your scenario is created for you in the location specified above.

6. Verify the scenario name and location.

7. Click Save .

> **Note:** Save Often!

Update the Insert STK Objects tool

Ensure the Launch Vehicle ( ) appears in the Insert STK Objects tool.

1. Click Edit Preferences... on the Insert STK Objects tool.

2. In the New Object list, select the object you want to add.

3. Click OK .

Launch Vehicle

Insert a **Launch Vehicle** Object.

1. Select Launch Vehicle ( ) in the Insert STK Objects tool.

2. Select the Insert Default method.

3. Click Insert... .

4. Rename LaunchVehicle1 ( ) LaunchToLEO.

Simple Ascent Propagator

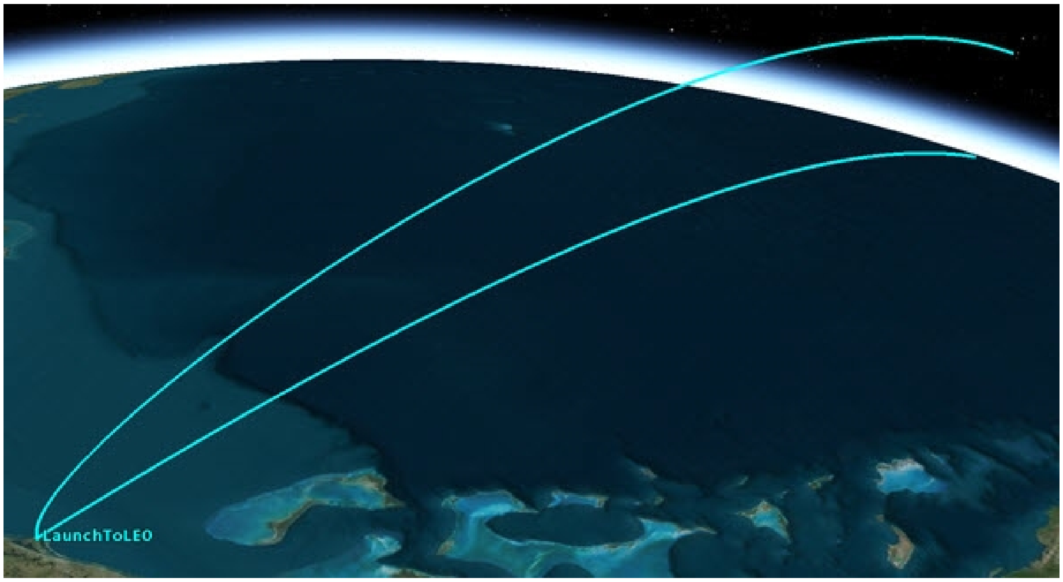
Use the **simple ascent propagator** to define the ascent trajectory from a launch point to an orbit insertion point.

1. Open LaunchToLEO's ( ) properties ( ).
2. Select the Basic - Trajectory page.
3. Ensure Propagator is set to SimpleAscent.
4. Set the Burnout Velocity value to 7.3 km/sec. This will keep the resulting orbit near circular.
5. Click **Apply** to accept the changes and keep the Properties Browser open.
6. Select the 2D Graphics - Attributes page.
7. Change the Color: to teal.
8. Click **OK** to accept the changes and close the Properties Browser.

View the Launch Vehicle Trajectory

View LaunchToLEO's ( ) launch vehicle trajectory and ground track in the 3D Graphics Window.

1. Bring the 3D Graphics window to the front.
2. Zoom To LaunchToLEO ( ).
3. Use your mouse to zoom out so you can see the launch vehicle trajectory and ground track.



LAUNCH VEHICLE TRAJECTORY

4. Note that the Launch Vehicle's ( ) default location is Cape Canaveral.

5. Notice the trajectory ends at burnout.

Insert A Satellite

Insert a Satellite ( ) object which you will use to create the satellite orbit.

1. Select Satellite ( ) in the Insert STK Objects tool.
2. Select the Insert Default method.
3. Click **Insert...** .
4. Rename Satellite ( ) GEO_Sat.

Astrogator

Set GEO_Sat's Propagator to ***Astrogator***. You will use *Astrogator* to design your spacecraft trajectory.

1. Open GEO_Sat's ( ) properties ( ).
2. Select the Basic - Orbit page.
3. Set Propagator: to *Astrogator*.

Mission Control Sequence

The **Mission Control Sequence** (MCS) is the core of your space mission scenario. The MCS functions as a graphical programming language, in which mission segments dictate how *Astrogator* calculates the trajectory of the spacecraft based on the general settings that you specify for the MCS itself.

The MCS is defined by selecting and organizing **MCS Segments** in a manner that produces your desired trajectory. By default, an *Astrogator* satellite's MCS contains two segments: an **Initial State** ( ) segment and a **Propagate** ( ) segment.

Initial State Segment

Since you model a Launch Vehicle ( ), remove the Initial State ( ) segment. You will replace it with a **Follow** ( ) segment .

1. Select Initial State ( ) in the MCS.
2. Click Delete Segment ( ).
3. Click **Yes** to confirm deletion.

Follow Segment

Use the Follow ( ) segment to set GEO_Sat ( ) to follow LaunchToLEO ( ), and then separate from LaunchToLEO ( ) at the end of its ephemeris.

1. Right-click the Propagate ( ) segment in the MCS.
2. Select Insert Before...
3. Select Follow ( ) in the Segment Selection window.
4. Click OK .
5. Ensure Follow ( ) is selected in the MCS.
6. Select the General tab on the Basic - Orbit page.
7. Click the Leader: ellipsis button ( ).
8. Select LaunchToLEO ( ) in the Select Leader window.
9. Click OK .
10. Set Joining: to Join at End of Leader's Ephemeris in the Additional Options section.

    By selecting this joining parameter, GEO_Sat ( ) uses the LaunchToLEO's ( ) final ephemeris point as the initial and final state of the Follow Segment. Also, the separation parameter is automatically set to "Separate at End of Leader's Ephemeris".

Fuel Tank Configuration

Set GEO_Sat's ( ) fuel mass and its maximum fuel mass.

1. Select the Fuel Tank tab.
2. Set the following in the order shown:

Option	Value
Maximum Fuel Mass:	6000 kg
Fuel Mass:	5000 kg

3. Click Apply .

Run the Mission Control Sequence

Run the Mission Control Sequence to calculate the trajectory of the spacecraft.

1. Select Propagate ( ) in the MCS.
2. Note the current stopping condition is Duration with a Trip: value of 43200 sec (0.5 day).
3. Click Run Entire Mission Control Sequence ( ) in the MCS toolbar.
4. When finished, bring the 3D Graphics window to the front.
5. Click Home View ( ) to view GEO_Sat's ( ) trajectory.

Satellite Engine Model

Use a realistic engine model in order to produce accurate results.

1. Click Component Browser ( ) in the MCS Toolbar.
2. Change Show: to *Astrogator* Components on the Component Browser window.
3. Select Engine Models in the Components list on the left.
4. Select Constant Thrust and Isp in the Engine Models list on the right.
5. Click duplicate ( ).
6. Change Name: to Test Engine in the Field Editor window.
7. Click OK .
8. Double-click on Test Engine in the Engine Models list.

Modify Constant Thrust and Isp

Modify the **Constant Thrust and Isp** engine model to specify the thrust and Isp for your engine.

1. Double-click on Thrust in the Engine Models - Test Engine window.
2. Set Real Number: to 13500 N in the Real Number Field window.
3. Click OK .
4. Double-click on Isp in the Engine Models - Test Engine window.
5. Set Real Number: to 2000 s in the Real Number Field window.
6. Click OK .

> **Note:** This high value will only affect the amount of fuel that we burn through over the course of the maneuvers. We are doing this so that we do not need to modify the spacecraft mass values several times over the course of the mission.

7. Click **OK** to close the Engine Models - Test Engine window.
8. Close () the Component Browser.

Transfer Orbit Injection (TOI)

Use the Propagate segment () to fly to the first maneuver time. The orbit is circular and therefore the burn can take place at any time and result in a similar delta-v. You require an inclination as close as possible to zero once you enter GEO. In order to minimize the required delta-v to both circularize and change inclination at GEO, we will combine those maneuvers into one. For that to be successful, the apogee of the transfer orbit will be the ascending or descending node of the orbit. This can be achieved by starting the TOI burn on either the ascending or descending node.

1. Return to GEO_Sat's () properties ().
2. Right-click on Propagate () in the MCS.
3. Select Rename.
4. Change the name to Prop_to_TOI.

Update the Stopping Condition

Update the Propagate Stopping Condition to stop at the ascending node after 2 full revolutions in the parking orbit.

1. Click New () in the Stopping Conditions section.
2. Select AscendingNode in the New Stopping Condition window.

3. Click OK .
4. Select the Duration stopping condition.
5. Click Delete ( ).
6. Change Repeat Count: to 2 so will stop it on the second ascending node.
7. Click Apply .
8. Click Run Entire Mission Control Sequence ( ).

Define a Target Sequence - Start Transfer

Insert a **Target Sequence** ( ). We will use a Target Sequence to calculate the Delta-V required to move GEO_Sat ( ) into a transfer orbit.

1. Return to GEO_Sat's ( ) properties ( ).
2. Right-click on Prop_To_TOI ( ) in the MCS.
3. Select Insert After...
4. Select Target Sequence ( ) in the Segment Selection window.
5. Click OK .
6. Right-click on Target Sequence ( ) in the MCS.
7. Select Rename.
8. Change the name to Start_Transfer.

Insert a Maneuver Segment

Insert a Maneuver ( ) Segment. This first maneuver delta-v will be solved to achieve a particular altitude at the end of the transfer ellipse.

1. Right-click on Start_Transfer ( ) in the MCS.
2. Select Insert After...
3. Select Maneuver ( ) in the Segment Selection window.
4. Click OK .

   The Maneuver ( ) Segment appears below the Return ( ) Segment.

5. Drag and drop the Maneuver ( ) Segment below Start_Transfer ( ).
6. Right-click on the Maneuver ( ) Segment.
7. Select Properties...
8. Change Name: to TOI
9. Change Color: to white.
10. Click OK .

Insert a Propagate Segment

Insert a Propagate ( ) segment that will be used to determine the stopping condition.

1. Right-click on TOI ( ) in the MCS.
2. Select Insert After...
3. Select Propagate ( ) in the Segment Select window.

4. Click OK .
5. Right-click on the new Propagate ( ) Segment.
6. Select Properties...
7. Set Name: to Transfer.
8. Set Color: to Yellow.
9. Click OK .
10. Click Apply .

Set the Engine Model

Use the Test Engine model you updated earlier.

1. Select TOI ( ) in the MCS.
2. Select the Engine tab.
3. Click the Engine Model ellipsis button ( ) in the Propulsion Type section.
4. Select Test Engine ( ) in the Select EngineModel window.
5. Click OK .

Select the Control Parameter

Select Delta-V Magnitude as the independent variable.

1. Select the Attitude tab.
2. Note that the default Attitude Control: is Along Velocity Vector (body X).
3. Click the target icon ( ) to target the Delta-V Magnitude and make it the independent variable.

This tells *Astrogator* to determine the delta-v magnitude based on user determined results. We will set up those results in an upcoming section.

4. Click **Apply** .

Propagate to Apoapsis

Update the Transfer ( ) Stopping Condition to stop at Apoapsis.

1. Select Transfer ( ) in the MCS.
2. Click New ( ) in the Stopping Conditions section.
3. Select Apoapsis ( ) in the New Stopping Condition window.
4. Click **OK** .
5. Select Duration in the Stopping Conditions section.
6. Click Delete ( ).
7. Click **Apply** .

Select the Results Variable

Set the radius of orbit, R Mag, as the equality constraint. *Astrogator* will use R Mag to determine the required delta-v magnitude.

1. Select Transfer ( ) in the MCS.
2. Click **Results...** at the bottom of the MCS.
3. Expand ( ) Spherical Elems in the User - Selected Results window's Available Components: list.
4. Move ( ) R Mag ( ) to the selected components list. This will allow you to set the radius of orbit at the

end of the Propagate Segment.

5. Click OK .

Set Up the Targeter

Set up the **differential corrector profile** to change the Delta-V Magnitude to achieve a desired radius of orbit.

1. Select Start_Transfer ( ) in the MCS.
2. Change Action: to Run active profiles.
3. Select Differential Corrector in the Profiles section.
4. Click Properties ( ).

Set the Control Parameter

Use Delta-V Magnitude as the Control Parameter (independent variable).

1. Locate the Control Parameters section of the Differential Corrector window.
2. Select Use for ImpulsiveMnvr.Pointing.Spherical.Magnitude.

Set the Equality Constraints (Results)

Use R_Mag as the Equality Constraint (dependent variable), and set the radius of orbit goal to be 42238 km.

1. Locate the Equality Constraints (Results) section of the Differential Corrector window.
2. Select Use for R_Mag.
3. Select the Desired Value field.
4. Set Desired Value to 42238 km.

5. Click OK .

6. Click Apply .

Run Entire Mission Control Sequence

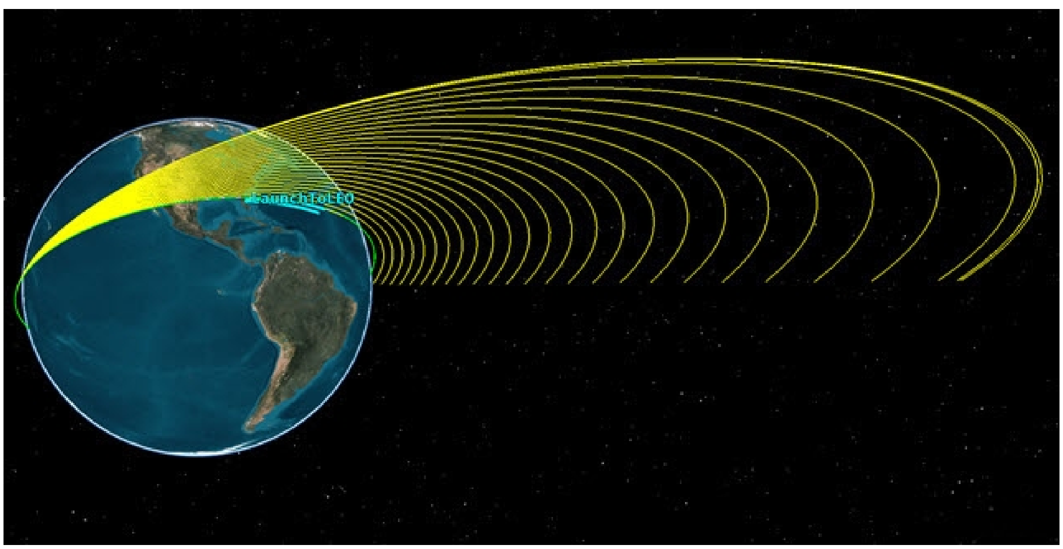
1. Save () your scenario

2. Click Run Entire Mission Control Sequence ().

3. When complete, look at the top of STK. You will see a message informing you whether or not running the entire mission control Sequence converged or didn't converge.

4. Look at the StartTransfer.Differential Corrector data window which shows you data based on running the active profile.

5. Bring the 3D Graphics window to the front. You can see the iterations, the last one placing the satellite at the desired location and altitude.



TOI ITERATIONS

Define a Target Sequence - Finish Transfer

Now that the transfer has been analyzed, a similar process will be followed to create the SOI maneuver and circularize the orbit at GEO, and at the same time, bring the inclination to 2 deg. We will target the inclination slightly above the desired inclination, so that it will drift down to the desired inclination (0 to 1 degree) over time.

1. Return to GEO_Sat's ( ) properties ( ).
2. Right-click on the bottom Return ( ) Segment in the MCS.
3. Select Insert Before...
4. Select Target Sequence ( ) in the Segment Selection window.
5. Click OK .
6. Right-click on Target Sequence ( ) in the MCS.
7. Select Rename.
8. Change the name to Finish_Transfer.

Insert a Maneuver Segment

Insert a Maneuver ( ) Segment. We will solve for the X (Velocity) & Y (Normal) components, the Delta-V vector in those references axes, needed to achieve a circular orbit at GEO.

1. Right-click on Finish_Transfer ( ) in the MCS.
2. Select Insert After...
3. Select Maneuver ( ) in the Segment Selection window.
4. Click OK .

The Maneuver ( ) Segment appears below the return ( ) Segment.

5. Drag and drop the Maneuver ( ) Segment below the Finish_Transfer ( ).

6. Right-click on the Maneuver ( ) Segment.

7. Select Properties...

8. Change Name: to SOI.

9. Change Color: to white.

10. Click OK .

Insert a Propagate Segment

Insert a Propagate ( ) Segment will be used to determine the stopping condition.

1. Right-click on SOI ( ) in the MCS.

2. Select Insert After...

3. Select Propagate ( ) in the Segment Select window.

4. Click OK .

5. Right-click on the new Propagate ( ) Segment.

6. Select Properties...

7. Set Name: to Prop1Rev.

8. Set Color: to Blue.

9. Click OK .

10. Click Apply .

Set the Engine Model

Use the Test Engine model you updated earlier.

1. Select SOI ( ) in the MCS
2. Select the Engine tab.
3. Click the Engine Model ellipsis button ( ) in the Propulsion Type section.
4. Select Test Engine ( ) in the Select EngineModel window.
5. Click **OK** .

Select the Control Parameter

Use Thrust Vector as the attitude control setting. Then select the Delta-V vector's Cartesian X (Velocity) and Y (Normal) as the independent variables.

1. Select the Attitude tab.
2. Set Attitude Control: to Thrust Vector.
3. Click the target icon ( ) next to X (Velocity).
4. Click the target icon ( ) next to Y (Normal).
5. Click **Apply** .

Propagate for One Day

Update the Prop1Rev ( ) Duration Stopping Condition to stop after 1 day.

1. Select Prop1Rev () in the MCS.
2. Change Trip: to 86400 sec (1 day) in the Stopping Conditions section.
3. Click **Apply** .

Select the Results Variable

Set Eccentricity and Inclination as the equality constraints.

1. Select Prop1Rev () in the MCS.
2. Click **Results...** at the bottom of the MCS.
3. Expand (⊞) Keplerian Elems in the User - Selected Results window's Available Components: list.
4. Move () Eccentricity () to the selected components list.
5. Move () Inclination () to the selected components list.
6. Click **OK** .

Set Up the Targeter

Set up the differential corrector profile to change the Delta-V Magnitude to achieve a desired radius of orbit.

1. Select Finish_Transfer () in the MCS.
2. Change Action: to Run active profiles.
3. Select Differential Corrector in the Profiles section.
4. Click Properties ().

Set the Control Parameter

Use Delta-V vector's Cartesian X (Velocity) and Y (Normal) as the Control Parameters (independent variables).

1. Locate the Control Parameters section of the Differential Corrector window.
2. Select Use for ImpulsiveMnvr.Pointing.Cartesian.X.
3. Select Use for ImpulsiveMnvr.Pointing.Cartesian.Y.

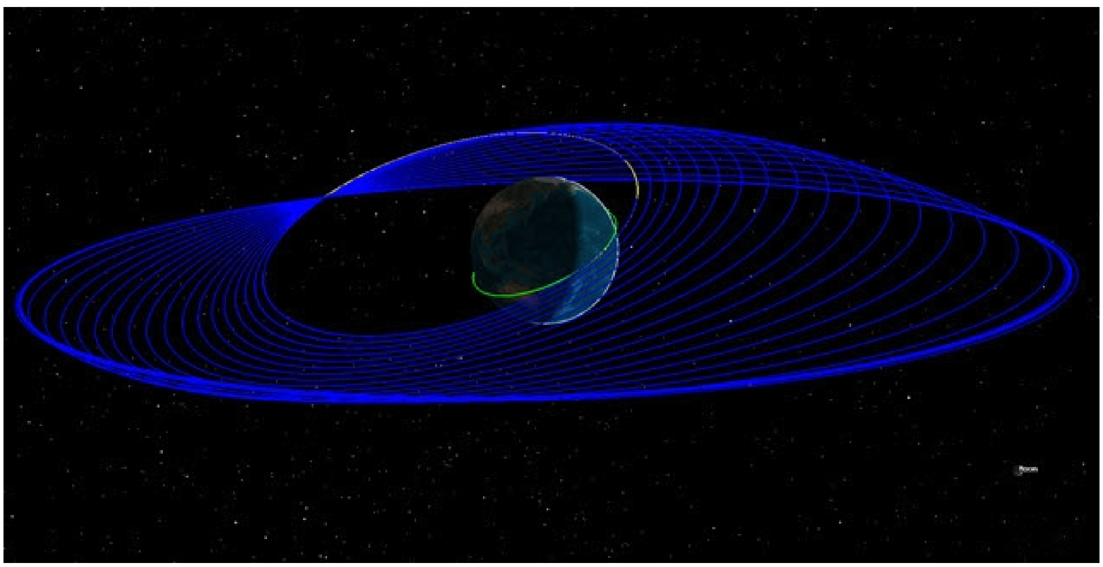
Set the Equality Constraints (Results)

Set Eccentricity and Inclination as the Equality Constraints (dependent variables). Target an Eccentricity of 0 within a 0.001 tolerance, and a 2 deg Inclination within 0.01 deg tolerance.

1. Locate the Equality Constraints (Results) section of the Differential Corrector window.
2. Select Use for Eccentricity.
3. Set Tolerance to 0.001.
4. Select Use for Inclination.
5. Select the Desired Value field.
6. Set Desired Value to 2 deg.
7. Set Tolerance to 0.01 deg.
8. Set Method: to By tolerance in the Scaling section.
9. Click OK .
10. Click Apply .

Run Entire Mission Control Sequence

1. Save ( ) your scenario
2. Click Run Entire Mission Control Sequence ( ).
3. Look at the Finish Transfer.Differential Corrector data window which shows you data based on running the active profile.
4. Bring the 3D Graphics window to the front. You can see the iterations, the last one placing the satellite at the desired eccentricity and inclination.

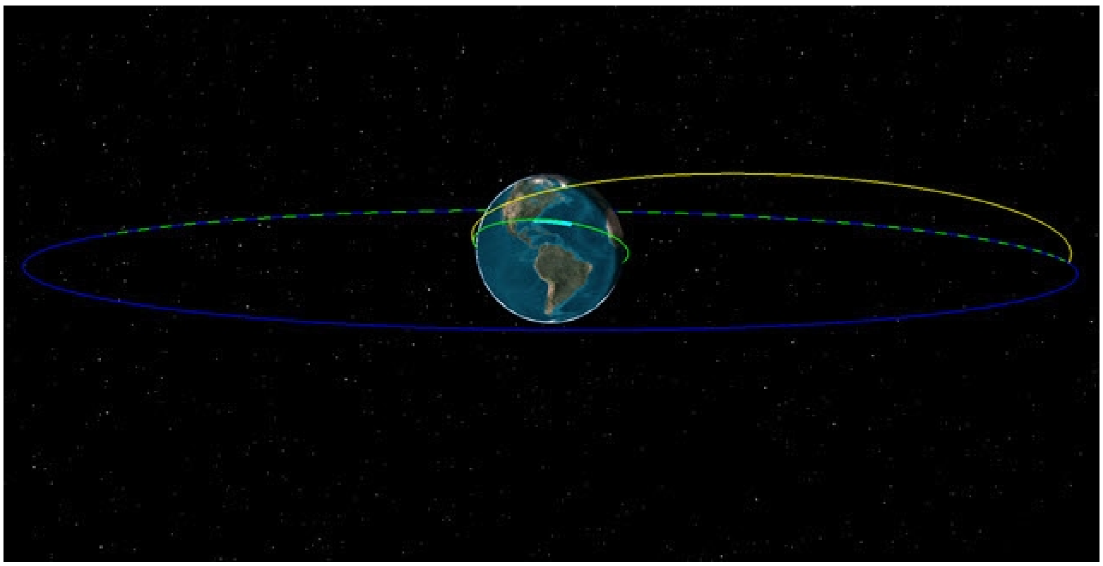


SOI ITERATIONS

Remove Iterations

Remove the visible iterations in the 3D Graphics window.

1. Return to GEO_Sat's ( ) properties ( ).
2. Right-click on the Bottom Return ( ) Segment.
3. Select Insert Before...
4. Select Propagate ( ) on the Segment Selection window.
5. Click OK .
6. Click Run Entire Mission Control Sequence ( ).
7. Bring the 3D Graphics window to the front.



FINAL ORBIT

MCS Segment Summary Report

The **MCS Segment Summary report** provides run summary data for the currently selected segment in the MCS tree. The summary report gives information on maneuver times, expected delta-v magnitude, estimated burn duration, estimated fuel usage and other important data.

1. Return to GEO_Sat's ( ) properties ( ).
2. Select Start_Transfer ( ) in the MCS.
3. Click Summary ( ) in the MCS Toolbar.
4. When finished, close ( ) the summary report.
5. Select Finish_Transfer ( ).
6. Click Summary ( ) in the MCS Toolbar.
7. When finished looking through the report, close any reports, tools and properties you still have open.
8. Save ( ) your work.

Summary

This was a basic introduction to *Astrogator*. In this lesson, you:

1. Used a Launch Vehicle object to launch a vehicle that followed an ascent trajectory from a launch point to an orbit insertion point.
2. Inserted a Satellite object, switched the propagator to *Astrogator*, and used a Follow Segment. This allowed the Satellite to follow the Launch Vehicle object, to separate from the Launch Vehicle at the end of its trajectory, and to place the Satellite object into a LEO.
3. Used a Target Sequence, a Maneuver Segment, and a Propagate Segment, to place the Satellite orbit into a TOI.
4. Finalized its orbit by creating another Target Sequence which placed the Satellite into a GEO.
5. Used an MCS Segment Summary Report to determine maneuver times, required delta-v, estimated burn duration, and estimated fuel usage.

On Your Own

Throughout the tutorial, hyperlinks were provided that pointed to in depth information of various tools and functions. Now is a good time to go back through this tutorial and view that information. Further *Astrogator* tutorials can be found **HERE**.

Part 16: Air to missile observations with STK EOIR capability

Required Product Licenses: STK Premium (Air), STK Premium (Space), or STK Enterprise
You can obtain the necessary licenses for this training by contacting AGI Support at **support@agi.com** or 1-800-924-7244.

Important: Additional installation - EOIR. You can obtain the necessary install by visiting **http://support.agi.com/downloads** or calling AGI support.

Note: The results of the tutorial may vary depending on the user settings and data enabled (online operations, terrain server, dynamic Earth data, etc.). It is acceptable to have different results.

Capabilities covered

This lesson covers the following STK Capabilities:

- STK Pro
- Electro-Optical Infrared Sensor Performance (EOIR)

Problem statement

To succeed in an upcoming mission, you need to determine when a system can detect, track, identify, and characterize targets of interest under operational conditions. You know that modeling and simulating these operations with a set of different tools can take far too long and is prone to mistakes. You need a single, physics-based, multi-domain analysis platform to accelerate your work.

Solution

This lesson will guide you through STK's *EOIR* capability at a basic level. You will model an observation system on an aircraft. You will track a missile and use *EOIR* to see what the camera on the aircraft would see. You will do this by generating an *EOIR* Synthetic Scene.

Once you complete this tutorial, you will be able to:

1. Design an air-based observation system
2. Build a mid-wavelength infrared camera
3. Analyze synthetic scenes and data

For more information and to see other examples of *EOIR*, please check out the available topics on the **Help Welcome page**.

Define the scenario’s environment

You will be creating a new scenario.

1. Click the Create a Scenario ( ) button.
2. Enter the following in the New Scenario Wizard:

Option	Value
Name	EOIR_AirObservations
Start Time	Default Start Time
Stop Time	+ 0 .5 days

3. Click **OK** .

Verify EOIR is installed

EOIR is a separate install. You can obtain the necessary install by visiting **http://support.agi.com/downloads** or calling AGI support.

1. If you do not see the EOIR toolbar ( ), extend the View menu.
2. Select the Toolbars option
3. Select EOIR.

Turn off terrain

In this analysis, we will not be utilizing the streaming terrain imagery, the missions will be in the air.

1. Open EOIR_AirObservations's ( ) properties.
2. Select the Basic - Terrain page.
3. Clear the Use Terrain Server for Analysis check box.
4. Click **OK** .

Insert an Aircraft object

Create the object the camera system will be placed on. For this setup we will model a quick flight path and observe a missile from launch to impact.

1. Insert a Aircraft ( ) object using the Define Properties ( ) method.
2. Set the following for the aircraft waypoints, leave the non-specific values as the default

Latitude	Longitude	Altitude	Turn Radius
33.00 deg	-80.00 deg	20.00 km	1.00 km
32.00 deg	-77.00 deg	20.00 km	1.00 km

3. Click OK to save your changes

Insert a Missile object

The target object will be the missile, set the following launch and impact points and leave all others as the default.

1. Insert a Missile ( ) object using the Define Properties ( ) method.
2. Enter 30 deg in the Launch Latitude - Geodetic field.
3. Enter -80 deg in the Launch Longitude field.
4. Enter 35 deg in the Impact Latitude -Geodetic field.
5. Enter -75 deg in the Impact Longitude field.
6. Set the missile speed to 5 km/sec in the Delta V field.
7. Click Apply .

Missile – EOIR Shape

Next, setup the EOIR Shape for the missile. This will define what the sensor will see when it targets the missile. We will create a generic missile, a cylinder with a cone on top.

1. Navigate to the Basic – EOIR Shape.
2. Set Component 1.

Option	Value
Shape:	Cylinder
Height:	50 m
Radius:	10 m
Body Temperature:	Static
Temperature:	500 K

3. Click Add next to the Component Panel.
4. Set Component 2.

Option	Value
Shape:	Cone
Height:	50 m
Radius:	10 m
Body Temperature:	Static
Temperature:	500 K

5. Click Apply to save your changes.

Missile – EOIR Stage

The missile has a burn as it takes off. Take a look at the burn in the EOIR Stage tab for the missile.

1. Navigate to the Basic – EOIR Stage.
2. Examine time On Time Delta and Off Time Delta. By default, the missile burns for a minute. Let's change this parameter.

3. Set the Off Time Delta to 30 sec.
4. Click OK to save your changes.

Insert a Sensor object

Bring a sensor object into the scenario. This will be the camera that tracks and follows the missile. We will place the camera on the nose of the aircraft and track the missile.

1. Insert a Sensor () object using the Insert Default method.
2. On the Select Object window, attach the sensor to the aircraft.
3. Open the sensor's properties.
4. Navigate to the Basic - Location.

Option	Value
Type:	Fixed
Fixed Location - Type:	Cartesian
X:	0.018 km
Y:	0 km
Z:	0 km

5. Navigate to the Basic - Pointing.

Option	Value
Pointing Type:	Targeted
Assigned Target:	Missile Object

6. Click Apply .

EOIR settings

Set the *EOIR* parameters for the sensor. We will work through each tab on the Basic-Definition page to define the system.

Set the Sensor Type to EOIR

Model an *EOIR* sensor type with one band. *EOIR* supports up to 36 bands per sensor. We will have one band for our analysis.

1. Select the Basic - Definition page.
2. Set the Sensor Type to *EOIR*.
3. Double-click in the Band name field.
4. Rename the band MWIR. This is short for Mid-wave Infrared, which is the part of the spectrum we're analyzing.

EOIR Settings – Spatial

The Spatial tab contains the spatial information of the sensor. This is where you define the total field-of-view angles and the number of pixels on the sensor detector.

1. Set the Field of View section on the Spatial tab:

Option	Value
Vertical Half Angle	0.02 deg
Horizontal Half Angle	0.02 deg

2. Leave the Number of Pixels as the default.

EOIR Settings - Spectral

The Spectral tab is where you define the spectral range of your sensor. The sensor model samples your spectral band using the number of intervals you define. The more intervals you have, the higher the accuracy of the analysis. However, more intervals mean longer computation time.

1. Select the Spectral tab.

2. Set the Spectral Band Edge Wavelengths section as follows:

Option	Value
High	5.50 um
Low	3.00 um

> **Note:** You must enter the High value before the low value to avoid errors.

3. Leave the Number of Intervals as the default.

EOIR Settings - Optical

1. Select the Optical tab.

2. Set the following values:

Option	Value
Input:	Focal Length and Entrance Pupil Diameter
Effective Focal Length:	415.00 cm
Entrance Pupil Diameter:	100.00 cm

3. Change the Image Quality to Negligible Aberrations.

The Image Quality property models wave front error through the optics. The Negligible Aberrations setting introduces 7% wave front error.

4. Leave the Optical Transmission and Diffraction Wavelength as the defaults.

EOIR Settings – Radiometric

1. Select the Radiometric tab
2. Set the Input to High Level
3. Set Sensitivity section values to:

Option	Value
Integration Time	100
Equivalent Value	1 e-15

4. Leave all other parameters as the defaults.
5. Click **OK** to save and close the properties.

Target the Missile object in EOIR

Once you've made your changes to the sensor, let's make sure it knows the behavior of the missile.

1. Click the EOIR Target Configuration ( ) button on the *EOIR* toolbar.
2. Highlight the Missile ( ) object from the list in the Available STK Objects panel.
3. Use the arrow button ( ) to move the missile to the Selected Targets list.
4. Click **OK**.

Generate the Synthetic Scene

The missile will launch from the ground, to make it easier to see move forward in the scenario by a few seconds.

1. Select the sensor in the Object Browser
2. Click the EOIR Synthetic Scene () button in the *EOIR* toolbar to generate an image that represents the sensor output.

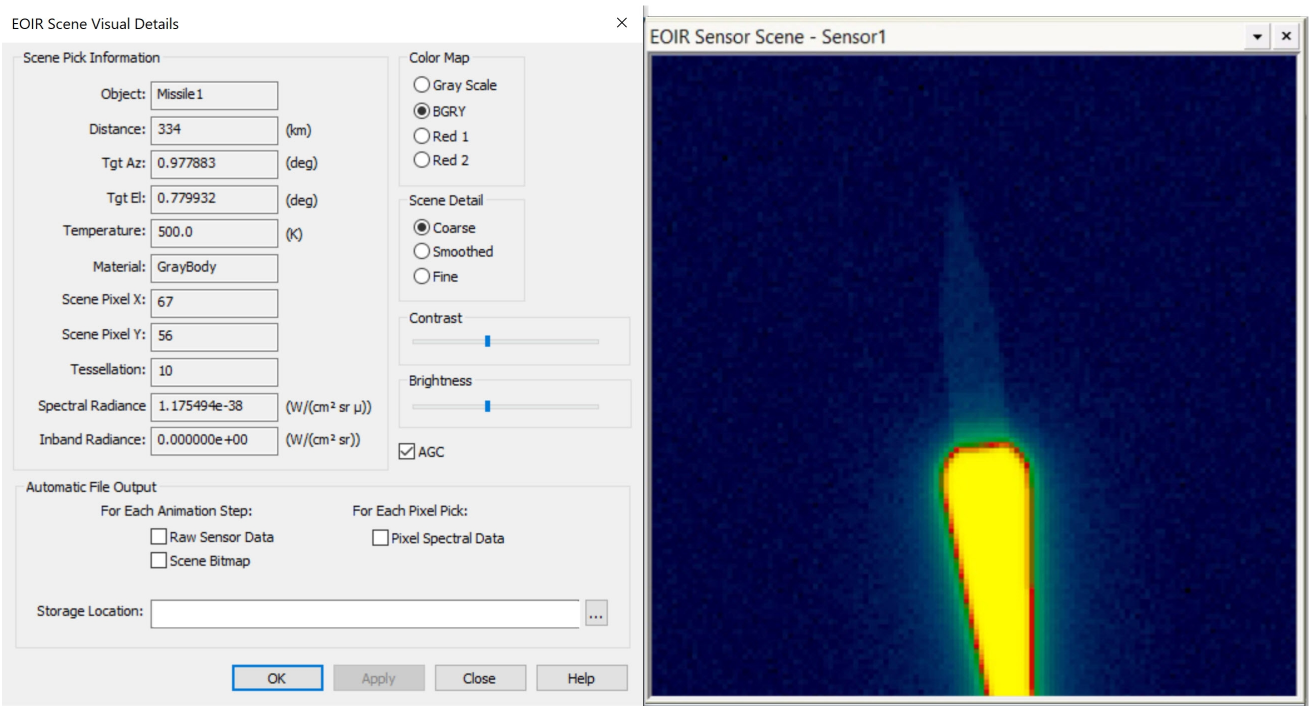
3. Right-click on the sensor scene and select Details....

The data in each sensor click can be saved to a file by selecting Pixel Spectral Data on the EOIR Scene Visual Details page. For the Sensor Output processing level, the raw sensor data and image can be saved out at every animation step. These images can be compounded to create a movie or run through external image processing software for further analysis.

4. Using your mouse click in the scene to generate information about each point in the scene.

5. Play around with the Color Map, take a look at the BGRY Color Map, and others

6. Click **Apply** .



7. Close the EOIR Scene Visual Details properties page when you finish.

8. Close the Synthetic Scene.

Examine an event

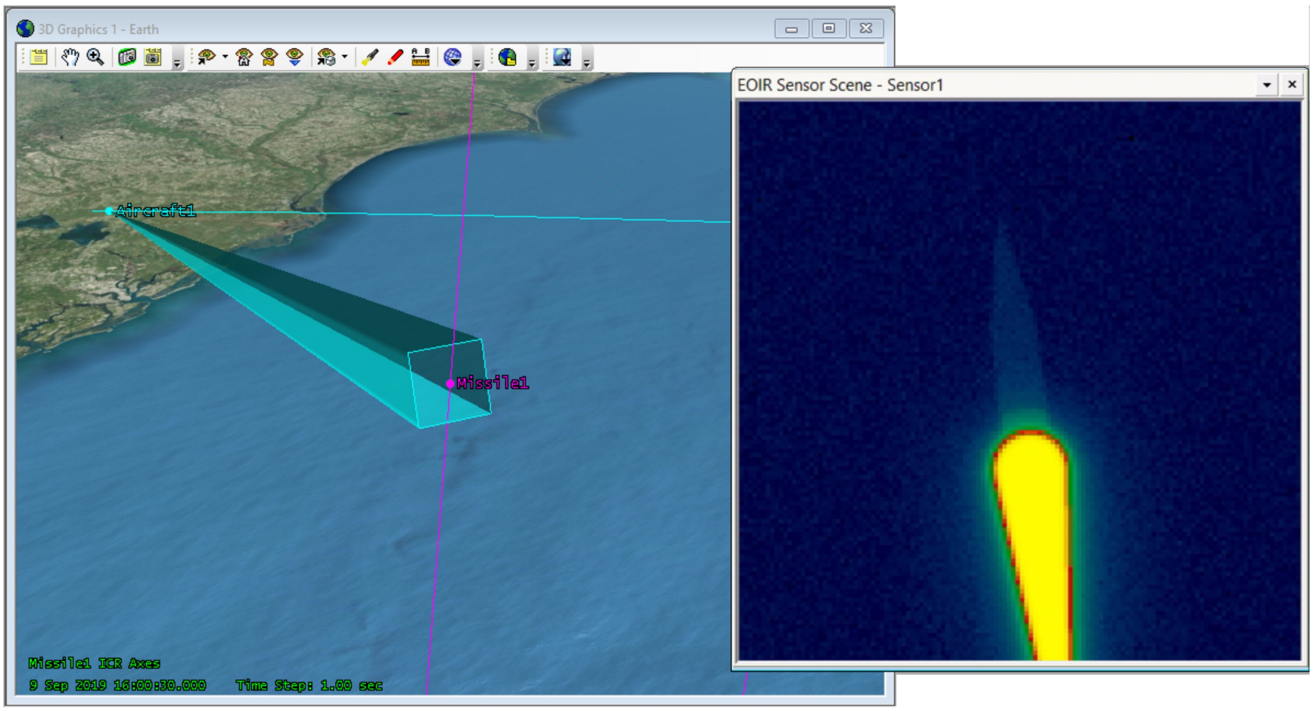
Our Missile is burning for the first 30 seconds of launch. Let's view what our sensor is seeing the moment before and after the burn ends.

1. Manually change the scenario time so that it is 30 seconds after your scenario start time (for example: 16:00:30.000).

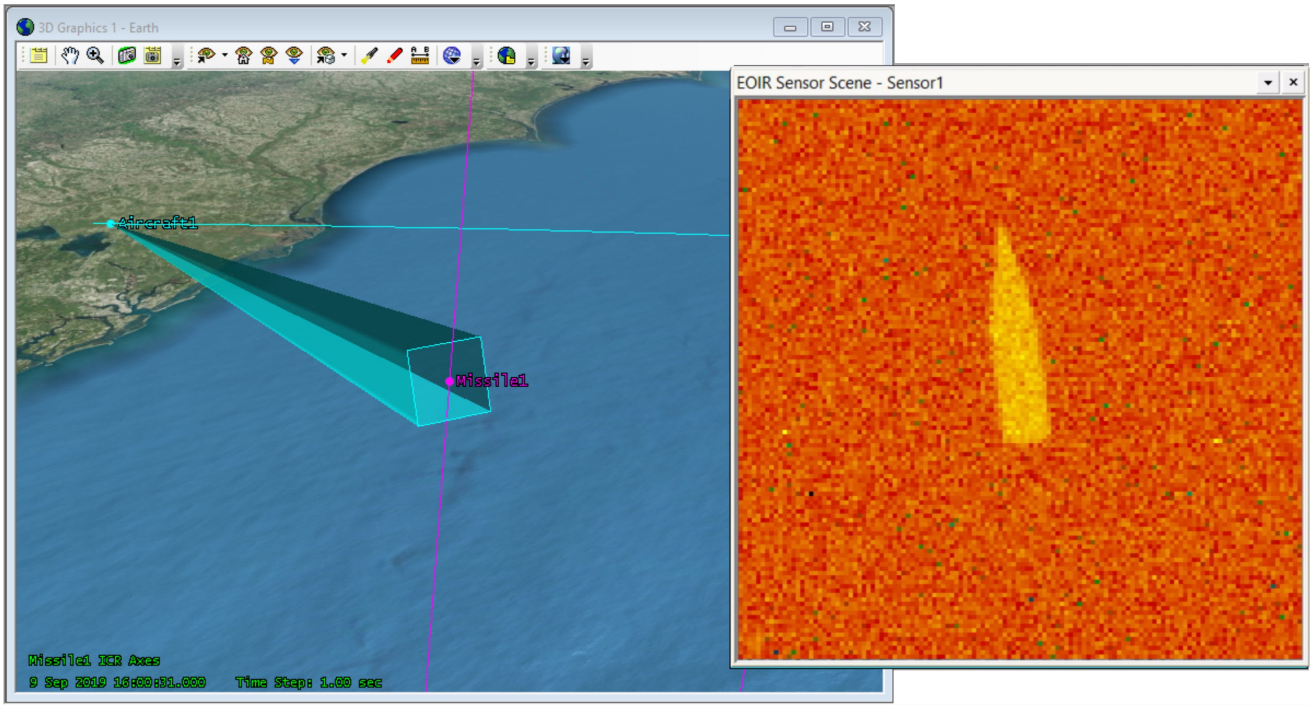
2. Examine your scenario and you should see your missile mid-flight.

3. Decrease the Time Step of your scenario so that it is set to 1 sec.

4. Regenerate your EOIR Synthetic Scene by clicking the EOIR Synthetic Scene ( ) button.



5. Use the animation Step Forward button to go one step (1 sec) past the end of the burn time. Examine your Synthetic Scene and note the changes. At this new moment in time there is no burn, so the leveling for the noise in your synthetic scene will also update.



Note: The image may vary based on the signal-to-noise ratio of the missile.

6. Close the Synthetic Scene when you finish.

Play around with the settings

Now that we've taken a look at the missile. Let's see how the system is affected when the target changes or if we make changes to the system

1. Navigate to Basic - EOIR Shape.
2. Set the Temperature of Component 1 to 1000 K.
3. Click **Apply** .

Note: The scene automatically regenerates if the image is open.

4. Take a look at the scene. How did changing the temperature affect the results?

Change the material

Let's see how changing the missile material changes the *EOIR* synthetic scene.

1. Go back to the Missile properties.
2. Set the Temperature back to 500K.
3. Set the Material to Aluminum MLI.
4. Click Apply. How did changing the material affect the results?
5. Change the Material back to Gray Body.
6. Click **OK** .
7. Close the Synthetic Scene.

Generate data

EOIR does more than simulate scenes created by an EO/IR sensor. It can also calculate metrics a sensor would receive from a target's signal. The following will familiarize you with some of the available *EOIR* data providers. Specifically, we will look at the Effective target radiance which measures the Power Flux Intensity. This is the average apparent radiance at the sensor aperture from a target object. Let's take a look at the information we get.

1. Right-click the Sensor ( ) and select Report & Graph Manager.
2. Click the Create a New Graph Style ( ) button to create a custom graph for the sensor.
3. Name the new graph: EOIR_TargetRadiance.
4. Open up the graph’s Content properties.

5. Move ( ) the Effective target radiance data element to the Y Axis in the *EOIR* Sensor to Target Metrics data provider.

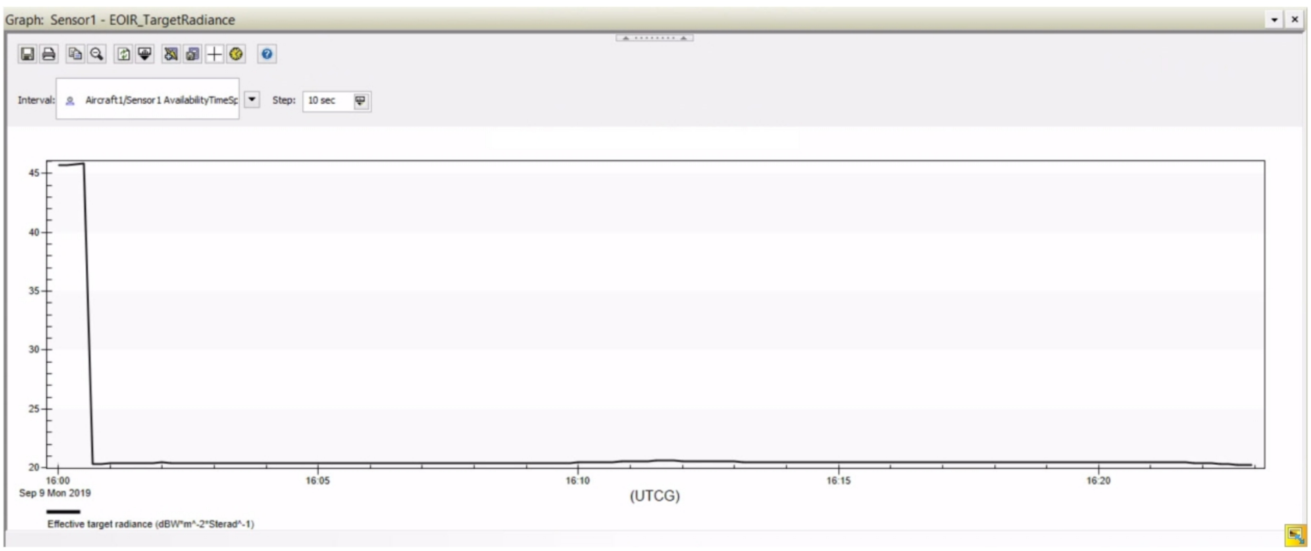
6. Click **OK** to finalize your custom graph and return to the Report & Graph Manager.

7. Double-click on the newly created graph. It may take STK a moment to generate the data.

8. Change the interval step size from the default time step to 10 sec.

9. Take a look at your targets behavior, do the results match the predicted behavior? Note when the missile burn turns off and how the radiance drops.

10. Use the magnifying glass to examine the radiance values after the burn has ended.



Save the Synthetic Scene information

Using connect commands, users can quickly export data from their *EOIR* synthetic scene. Run the below commands to pull out data from this mission.

Open the API Demo Utility

1. Select View on the menu bar.
2. Select Web Browser.
3. Click Browse () on the Web Browser toolbar.
4. Click Example HTML Utilities on the left.
5. Browse to STK Automation > API Demo.
6. Select the API Demo Utility.htm.
7. Click **Open** .

Run the connect command

The two commands we will run are to "SaveSceneImage" and "SaveSceneRawData". Refer to the **help resources** to find more information on these commands. We only have a single band in our mission (MWIR), however note that you can export data on multiple bands.

1. Set your scenario time to an instance that you want to pull data from (for example: 16:00:30.000).
2. Enter the lines below in the Code Sandbox. Change the file path to your scenario file path, or your preferred file path.

```
EOIRDetails */Aircraft/Aircraft1/Sensor/Sensor1 SaveSceneImage "C:/<user specified file path>/output_image.bmp" MWIR
```

```
EOIRDetails */Aircraft/Aircraft1/Sensor/Sensor1 SaveSceneRawData "C:/<user specified file path>/output_image.txt" MWIR
```

3. Click **Run Code** to execute the command.
4. Examine the files in your folder. They can be used for post processing or presentation.

Save your work

1. Close any open reports, properties, and the Report & Graph Manager.
2. Save () your work.

Summary

In this tutorial, you demonstrated how to build and analyze an observation system on an aircraft. You tracked a missile using an *EOIR* sensor to see what a camera on the aircraft would see and even generated data on it. This is especially useful information because you can see from your radiance graph that the signal is high during the initial burn but drops once the burn completes. Your ability to track and detect objects like missiles depends on the sensors we design and build for our missions.

On your own

Expand your mission: in this lesson, you modeled a single sensor and a single band. *EOIR* gives you the flexibility to model multiple sensors and bands for your mission. Try it out and see how your results may differ when looking at different parts of the spectrum. Use this lesson as a guide to expand all you can do with *EOIR*.

Become Level 2: STK Master Certified

Now that you have completed Comprehensive training, you are well-prepared to complete the STK Level 2 Certification test. The STK Master Certification is the second level of certification and validates your ability to perform more advanced STK modeling and analysis through use of STK's *Analysis Workbench*, *Astrogator*, *Aviator*, *Communications*, *Coverage*, and *Radar* capabilities.

What's in the Test?

The Level 2 - STK Master Certification test consists of four scenario development exercises and one bonus exercise. There are multiple choice questions for each exercise. You have 14 days from registration date to complete Master Certification. The following objectives are tested:

- Model Your Systems - Advanced Aircraft (Aviator), Advanced Satellite (Astrogator), Missile, Sensor, Constellation, Chain, Advanced Constraints, Terrain, *Communications*, *Radar*, RF Environment models, STK External Propagator, Vehicle Attitude
- Analyze Your Systems - Access Tool, Report & Graph Manager, Custom Reports, *Coverage*, Figure of Merit, *Analysis Workbench* (Vector Geometry Tool)
- Extend STK - Connect commands to model objects, enable constraints, and generate reports

Once you earn your STK Certification, you will receive a Level 2: STK Master Certified gift. Register now to take the Level 2: STK Master certification test (http://www.agi.com/training/#cert).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