Achieving Astrodynamics Consistency with the STK and ODTK Applications

Updated for STK / ODTK 13.0

The following information is meant to serve as guide to configuring the Ansys Systems Tool Kit® (STK®) and Ansys Orbit Determination (ODTK®) applications for computational consistency. It assumes that you are using version 13.0 (or later) of the STK and ODTK applications. The main areas of concern are Earth-centered coordinate transformations and orbit propagation. A necessary first step is to ensure that the same data are used in both products.

1 Dynamic Earth data

The STK and ODTK applications rely on the following data files:

EOP-v1.1.txt	This file contains the historical daily values for polar motion and UT1-UTC corrections for at least the previous five years. It also contains predicted values for the next year, as measured from your last update. There is another version of this file, EOP-All-v1.1.txt, which contains measured data back to 1962.
SpaceWeather-v1.2.txt	This file contains the historical values for the F10.7, Ap, and Kp parameters for the last five years. It also contains predicted values for the next 90 days, as measured from your last update. There is another version of this file, SpaceWeather-All-v.1.2.txt, which contains measured data back to 1957.

These files are located in the **C:\ProgramData\AGI\STK_ODTK 13\DynamicEarthData** directory for both applications.

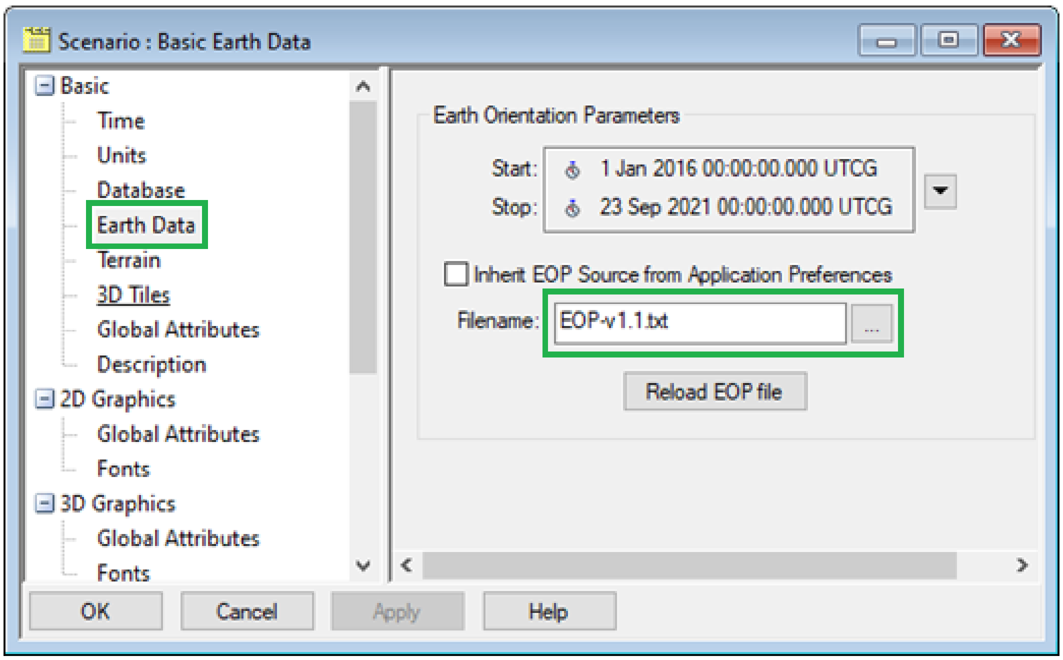
The parameters in these files change over time, so you must update the corresponding files in our products as appropriate. You can update each set of files using the Data Update utilities available in each application from their respective **Utilities → Data Update** menu. Both of these utilities obtain the necessary updates from an AGI resource.

The STK and ODTK applications share the dynamic Earth data files. If, for example you change the STK application to use the EOP-All-v1.1.txt file or to use an EOP file in a different location, then you must also separately configure the ODTK application to use the same file. In new scenarios, both products will use the same files for EOP and SpaceWeather by default.

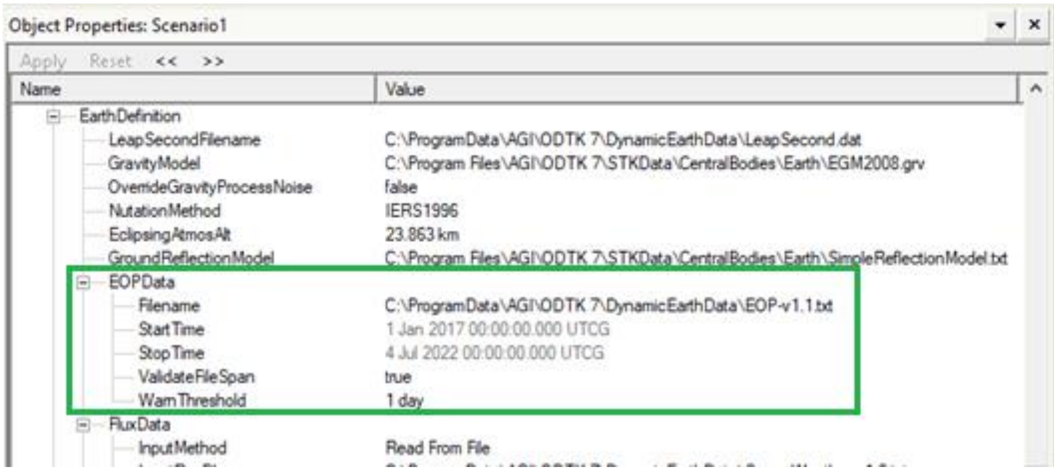
2 Coordinate transformations

2.1 Earth orientation parameters (EOP)

There are several Earth-related settings that must be consistent in both the STK and ODTK applications for Earth-centered coordinate transformations match. In the STK application, you can select the specific EOP file to be used on the **Basic → Earth Data** tab of the scenario property page.



The EOP file in the ODTK application is specified via the object properties on the scenario, as shown:



2.2 Earth central body (CB) file

Other settings of interest are in the **Earth.cb** central body file for both applications. The **Earth.cb** file is located in the ***<Install_dir>*\STKData\CentralBodies\Earth** directory and contains settings that define characteristics of the Earth. There is one copy of this file, so changes made there will be reflected in both applications. If you want to make changes to the central body file, place the updated version in the **C:\ProgramData\AGI\STK_ODTK 13\STKData\CentralBodies\Earth directory**. This directory does not exist by default, so you will need to create an **STKData** folder with corresponding subfolders inside the **C:\ProgramData\AGI\STK_ODTK 13** directory. The Earth properties defined in this folder will override the properties in the install directory. Maintaining changes in either the install or **ProgramData** areas will ensure that changes will be reflected in both applications. Maintaining separate central body files in other locations, such as STK scenario folders, will likely lead to inconsistencies and general frustration.

The **NutationUpdateInterval** and **NutationMethod** settings are necessary to ensure that transformations between Earth Inertial and Earth J2000 are identical between the applications. If you are not doing any analyses in Earth J2000, you will not need to perform these steps to synchronize the nutation settings.

The **NutationUpdateInterval** setting specifies how often (in seconds) the Earth nutation matrix is updated. The ODTK application disregards whatever value is specified in the file and uses zero. Therefore, for the STK application to match the ODTK application, this value should be left at its default of 0 seconds.

In the ODTK application, the **IAU1980NutationMethod** is overridden and set to the **IERS 1996** method by default. This specification indicates that the nutation is computed based on the IAU 1980 theory using the fundamental arguments from the 1996 IERS Conventions. The default value of **IAU1980NutationMethod** for the STK application is **JPLFile**, meaning that nutation is computed based on interpolation of the current JPL DE file. Both applications can be configured to use either method.

To have both applications use the **JPLFile** method, change the **NutationMethod** attribute in the ODTK application (see above screen shot) from **IERS1996** to **JPLFile**. The STK central body file in this case will not need to be modified.

To use the **IERS1996** nutation method in both applications, change the **NutationMethod** attribute in the ODTK application to **IERS1996** and modify the **Earth.cb** file for the STK application by un-commenting the line

```
#     IAU1980NutationMethod    IERS1996
```

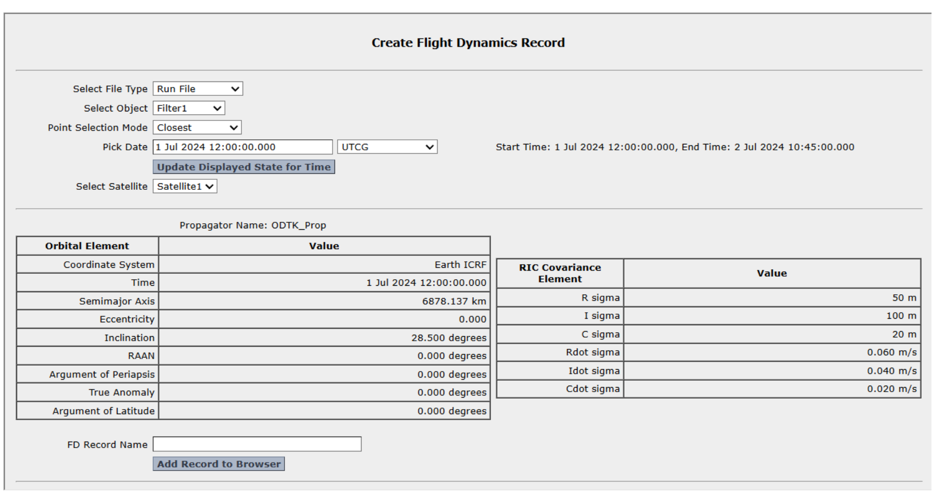
3 Astrogator orbit propagation

It is common practice to take a state vector from the ODTK application and propagate it using the STK/Astrogator® capability. For example, for maneuver planning, calibration, and reconstruction, ODTK outputs are processed by the Astrogator capability to calculate future maneuvers. This requires you to configure your Astrogator settings to achieve consistency with the ODTK application. With the Component Browser in both the ODTK and STK applications, it is simple to get identical force models between the two applications. If you want to share both an initial state and propagator between the applications, you can use a Flight Dynamics Record to do so. If you just want to share the propagator between the applications, you can export the Propagator in the Component Browser in one application and import it into the other application.

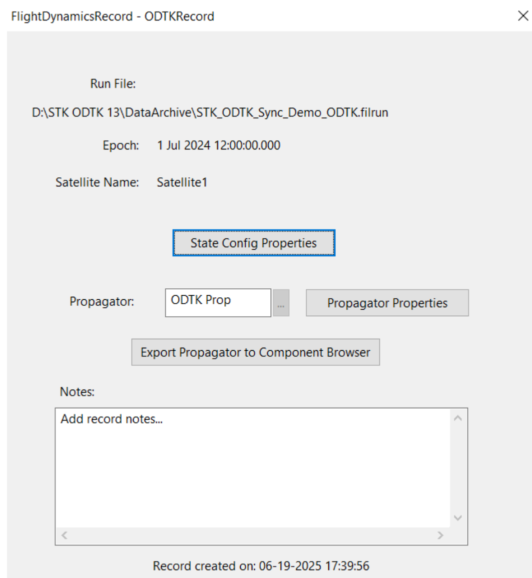
3.1 Sending a Flight Dynamics Record from the ODTK application to the STK application

3.1.1 Creating a Flight Dynamics Record in the ODTK application

You can create a Flight Dynamics Record in the ODTK application after running a filter, simulator, or smoother with at least one satellite. After running your desired process, go to the **Utilities** menu, select **All Utilities**, and double-click Flight Dynamics Record Creator.



Then, select whether you want to choose a state to transfer from a run file or restart record. Run files have states at every time update or process noise update step, while restart records are created at time intervals that you can specify as a user (they default to every hour). If you choose to pick a state from a run file, you will need to specify a desired time for your state as well as the object and satellite from which your state should come from. Then, clicking the Update Displayed State for Time button will display a preview of the state and uncertainty. If you choose to pick a state from a restart record, you will need to pick a time from the list of restart record times as well as the object and satellite from which your state should originate. In either the run file or restart record case, after you select a state, you can enter a name for your Flight Dynamics Record and then click the Add Record to Browser button. Then, you can inspect your Flight Dynamics Record in the corresponding folder in the Component Browser.



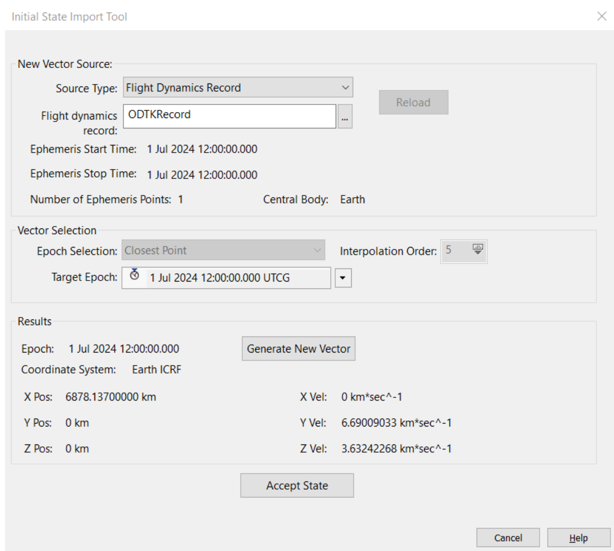
Opening up the properties enables you to view the State Config Properties, which shows information about the spacecraft’s state in the record, or the Propagator Properties, which contain the Propagator settings at the time the record was created. These Propagator settings will not update when the Propagator itself is changed; this is so that the Flight Dynamics Record properly records the settings when the record was created. If you would like to update the version of the Propagator in the Component Browser to be in sync with the version in the Flight Dynamics Record, use the Export Propagator to Component Browser button.

Once you’ve found your record in the Component Browser, click it and click the Export button to export the component to your file system.

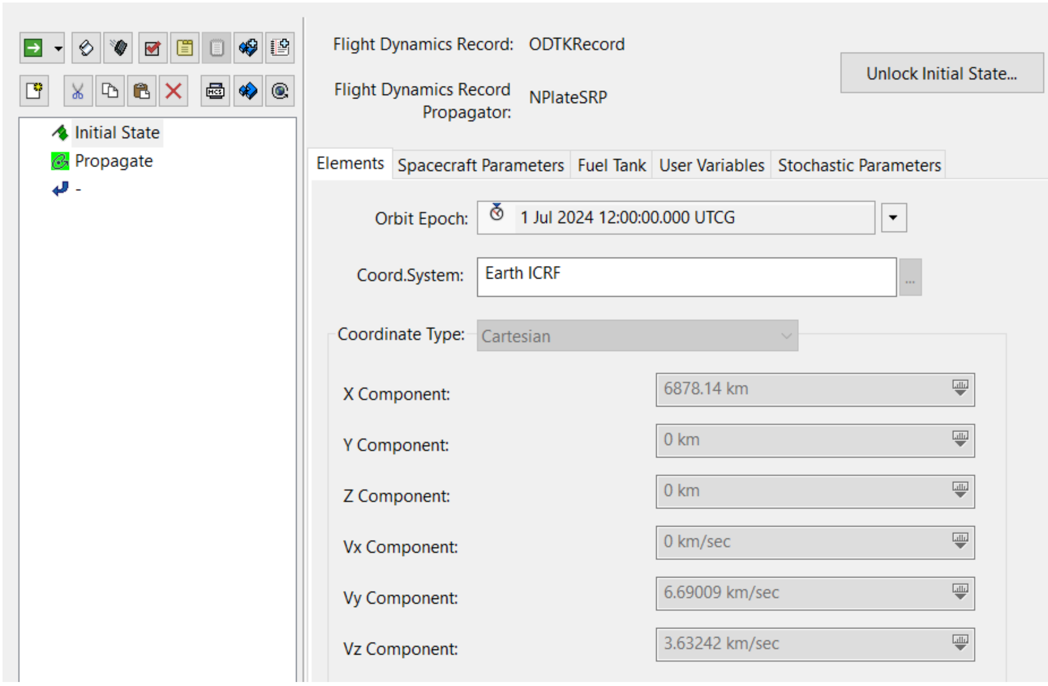
3.1.2 Importing the Flight Dynamics Record in the STK application

In the Component Browser, go to the Flight Dynamics Record folder. Then, click the import button (right next to the export button), and go to the location where you saved the Flight Dynamics Record. When importing a Flight Dynamics Record, it will automatically try to import the Propagator component that is in the record into the Component Browser if a Propagator with the same name doesn't already exist. Regardless, select the Initial State segment of your Astrogator satellite and click on the Initial State Tool button. Then, change Source Type to "Flight Dynamics Record" and select your desired Flight Dynamics Record from the Component Browser.

When importing a Flight Dynamics Record from the ODTK application, the current values and model parameters for stochastic elements of the state, such as corrections to the drag or solar pressure coefficients, are also brought into the STK application. Consistent modelling of the time evolution of these stochastic elements is required for consistency in orbit propagation results.



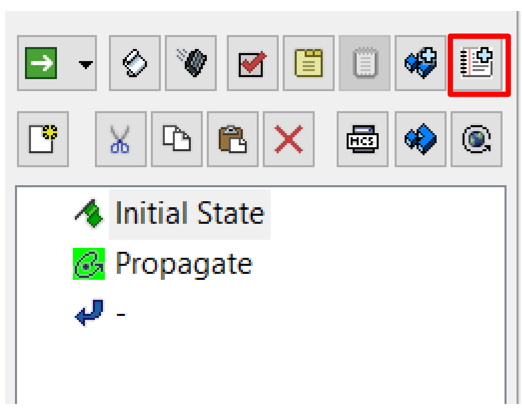
After clicking Accept State, the Initial State segment will become locked and set to the state that's in the Flight Dynamics Record. The epoch, position, velocity, spacecraft parameters, and the stochastic corrections to those parameters will be set on the initial state. To edit any of the values, you must first unlock the initial state, which will keep all the state values from the flight dynamics record and enable you to edit them.



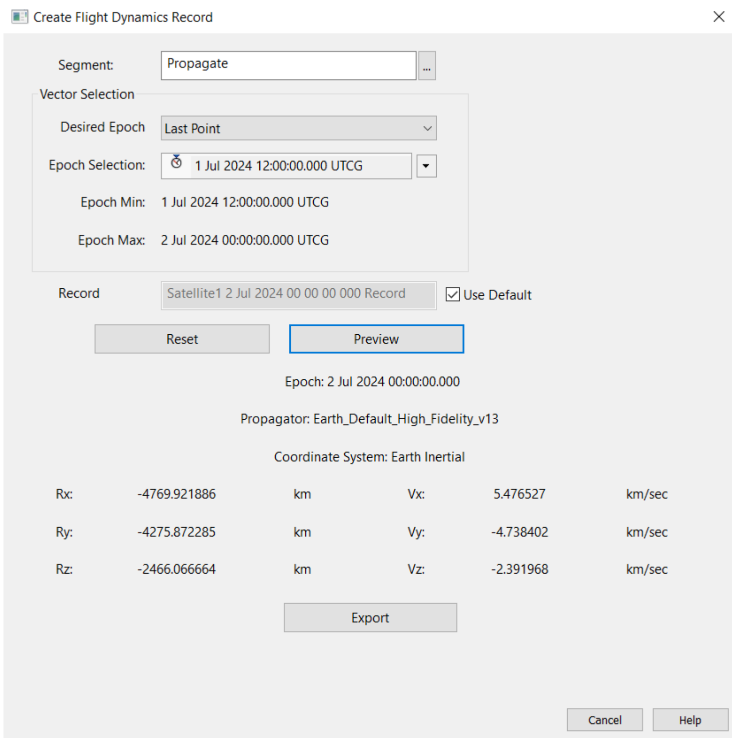
3.2 Sending a Flight Dynamics Record from the STK application to the ODTK application

3.2.1 Creating a Flight Dynamics Record in the STK application

You can create a Flight Dynamics Record in the STK application after an Astrogator satellite has been propagated. After propagating a satellite, click the “Add Flight Dynamics Record to Component Browser” icon on the MCS tree toolbar.



The Flight Dynamics Record creator provides the option to choose a particular state within a segment, and it will create a Flight Dynamics Record for the selected state. Clicking the Export button on the creator will put a Flight Dynamics Record in the Component Browser containing the selected state and the shown propagator. You can then export it to disk from the Component Browser.



3.2.2 Importing the Flight Dynamics Record in the ODTK application

First, you must import a Flight Dynamics Record into the ODTK Component Browser by clicking the Import icon. After doing so, open the Initial State Tool utility in the Utilities drop-down menu. Then, select “Flight Dynamics Record” for the Select Orbit Source option and choose the correct record from the Component Browser. Clicking Run will import the data from the Flight Dynamics Record, including setting the propagator named in the record from the Component Browser as the Propagator for the satellite.

3.3 Finite maneuvers

The Astrogator capability has a larger selection of options for the specification of finite maneuvers than ODTK software has. If your maneuvers do not fit into one of the ODTK-provided types, you will need to generate an acceleration history file from the STK application that describes the finite maneuver executed in the Astrogator capability and use the Acceleration History maneuver type for ODTK processing. Since the acceleration history is a time-ordered table of how the maneuver imparts acceleration on the spacecraft, the table must be interpolated during the numerical integration process. The data in the acceleration table must, therefore, be provided in a manner that supports accurate interpolation. Accurate interpolation mainly depends on the sampling rate of the acceleration profile and the specified interpolation order. The sample rate is driven by the step size of the propagator used during the maneuver in the Astrogator capability. Small step sizes, on the order of one second or less, are sometimes required for consistency in maneuver results. Use of third-order interpolation, specified in the acceleration history file, is typically required to provide accurate interpolation.

It is helpful to control the integration step size during the maneuver. The use of fixed step size integration at small step sizes is helpful.

3.4 Plugin acceleration models

Make sure that you are using the same version of plugin acceleration models between the two tools and that all settings of the plugins match exactly.

3.5 Numerical integrator

A list of numerical integrators is defined on the Propagator component in the Component Browser. This list, which contains the set of integrator settings, will be transferred between the applications along with the Propagator component. Ensure that the same integrators are selected in both the STK and ODTK applications. To achieve full precision consistency, the integrators must be configured to use a fixed step. The ODTK application forms time grids when it propagates. For example, for a simulator, that step is defined in Process Control/TimeStep. The fixed step you choose for the integrator must evenly divide the TimeStep selected for propagation to achieve exact consistency.

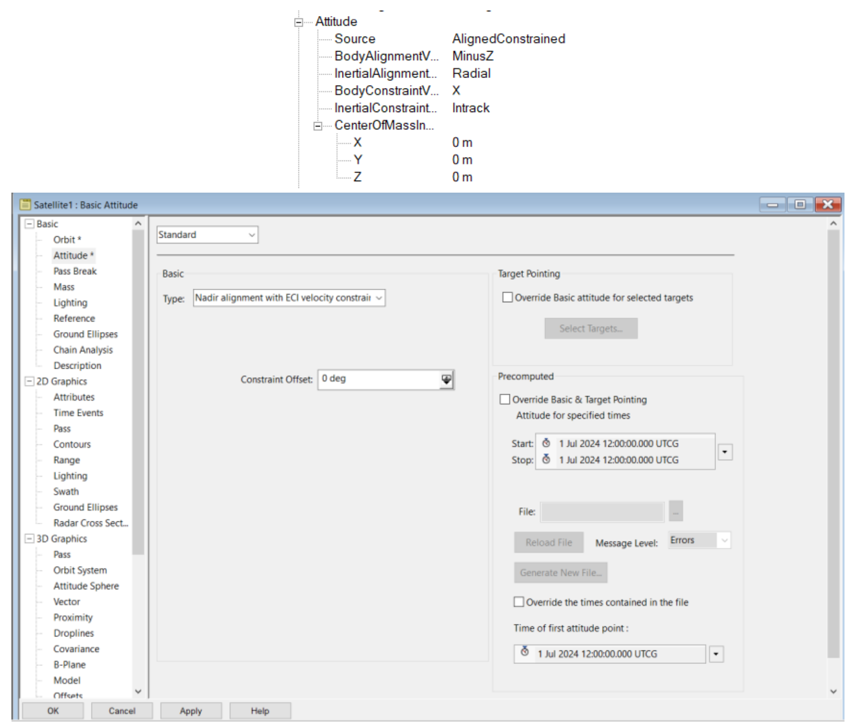
3.6 Solar pressure

In STK application version 13.0, there may be some numerical differences in the applications introduced if boundary mitigation is turned on. This difference occurs due to slight differences in how the STK and ODTK applications interpolate the state. These differences will be very small, but they may prevent you from getting full precision agreement between the applications. This will be addressed in a future version.

Additionally, when using GPS SRP models, the Astrogator capability does not allow you to propagate stochastic corrections for SRP coefficients. Flight Dynamics Record components will also not contain corrections to SRP coefficients for GPS SRP models. These will affect the ability to achieve consistency between the two tools if you are taking a state from a filter in the ODTK application and transferring it to the STK application. These will be addressed in a future version.

3.7 Attitude

The ODTK application defines its attitude settings in the satellite properties under Attitude. Satellites using the STK Astrogator capability may define their attitude in two places within the software. If there are no maneuvers for a satellite, then the attitude is defined in the Basic/Attitude options on the satellite. If there is a maneuver, then you can choose whether attitude is defined by the maneuver or in the Basic/Attitude options. If your force model involves the use of a drag or SRP model that depends on the spacecraft attitude, such as an N-Plate model, you will need to ensure that the STK and ODTK applications are configured to use identical attitude profiles to get identical propagation. By default, the ODTK application's settings are identical to the STK application's "Nadir alignment with ECI velocity constraint" option, which is the default.



4 Consistency testing

The easiest way to test whether you have achieved consistency is to propagate a state vector forward in time using each tool and compare the ephemerides. Ansys typically tests in the following manner:

1. Perform the following in the STK application:

    a. Create a satellite and call it AstrogatorTest. Configure the initial state to whatever state you want.

b. Configure the Propagator component to whatever settings you want as well. However, for the sake of comparison, make sure the propagator has a fixed-step integrator.

c. Open up the satellite's **Basic Properties**. In the **Propagate** segment, select the Propagator you created.

d. Propagate the satellite.

e. Create a Flight Dynamics Record from the initial state of the Astrogator satellite according to section 3.2.1 above.

2. Perform the following in the ODTK application:

    a. Import the Flight Dynamics Record into an ODTK satellite according to section 3.2.2 above. Make sure to set the integrator to be the fixed-step integrator.

    b. Propagate the satellite in ODTK and generate an STK External Ephemeris (.e) file.

3. Perform the following in the STK application:

    a. Create a satellite and call it ODTKTest. Set its propagator to be **External** and select your ephemeris file you created for the ODTK satellite above.

    b. Since you created the Flight Dynamics Record from the initial state of the satellite, the ODTK satellite has been set up to match the state you picked in the Astrogator capability.

    c. Select the ODTKTest satellite and generate a **RIC** graph. It will prompt you for the satellite to compare against; choose the AstrogatorTest satellite. Ensure the results are satisfactory to you. If not, then you have a configuration error somewhere. It is possible to get zeros for all time in the **RIC** graph if the STK and ODTK configurations are identical.

Alternatively, you can define the initial state and propagator in the ODTK application, create a Flight Dynamics Record in the ODTK application, and then import that into the STK application using the procedure in section 3.1. If there are any corrections to spacecraft parameters estimated by an ODTK filter execution, those corrections will be captured by the Flight Dynamics Record and propagated in the Astrogator capability.

5 Interpolator settings

If you are generating RIC reports (as opposed to graphs) and see jumps in differences that occur between the output ephemeris points, then you may be seeing issues due to two satellites having different interpolation methods.

For a satellite using external ephemeris in the STK application, the interpolation method is defined in the lines:

```
InterpolationMethod          Lagrange
InterpolationOrder           5
```