SkyTrack Help Document v1.6.6

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Installation

SkyTrack consists of a single executable file called skytrack.exe. It is downloaded as skytrack.exe or install_skytrack.exe.   The latter is a simple installation that creates a folder (default: c:\skytrack), copies the file skytrack.exe to the folder and creates a desktop icon. The user account must have read/write permissions to the SkyTrack folder (not having write permissions will result in TLE download and other failures)

Upon running SkyTrack for the first time, other files will be created in the folder:

skytrack.cfg	- contains configuration parameters, it is advised not to manually edit this file
skytrack_log.txt	- contains audit information for troubleshooting. This file is initialized each time the program executed. The previous file is copied to skytrack_log_old2.txt.
.tle/.txt	- downloaded TLE files containing satellite orbital elements
sdatabase.txt	- satellite information database
comets_d.txt	- comet database
asteroids_d.txt	- asteroids database

System Requirements

SkyTrack was developed and tested with Windows 10.   Windows 7 may also be used. A minimum screen resolution of 1366x768 is required. Other system requirements are minimal; the minimum requirements for Windows 10 would be satisfactory.

Other Software (optional)

If you wish to display Satellite/Solar system object transit lines on a map, please install Google Earth Pro for desktops (Copyright © 2021 Google LLC)

The following two plate solving software can be used to create satellite path models to improve mount pointing accuracy.

ASTAP plate solver available at https://www.hnsky.org/astap.htm

Astrometry.Net Local (ANSVR) plate solver available at https://adgsoftware.com/ansvr/

Satellite Tracking Methods

SkyTrack uses two methods of satellite tracking – "Leap Frog" and "Continuous" tracking. Starting with v1.5.1, compatible mounts using ASCOM may track using either "Leap Frog" or continuous tracking. Most legacy interfaces are capable of continuous tracking.

Leap Frog Tracking
With leap frog tracking, the mount slews ahead of the satellite in its path. It then pauses, allowing the satellite to drift through its field of view, then slews ahead of the satellite again and the process repeats. The slew ahead distance and drift wait time can be configured (both expressed in seconds).

Continuous Tracking
Continuous tracking attempts to smoothly track the moving satellite, keeping it in the field of view continuously. This is accomplished by two different methods, frequently sending variable rate slew commands to the mount or sending a rapid sequence of "goto" commands to the mount (classic LX200 only).

ASCOM based continuous tracking is available for compatible mounts. To effectively facilitate continuous tracking a couple capabilities are required;

- ASCOM method "MoveAxis" must support variable rates.
- When issuing ASCOM "GetRightAscension" and "GetDeclination", the driver must return near "real time" position data. Some drivers only update the position at timed intervals. For example, if the data is only renewed internally once a second, and the satellite being tracked is moving at 2 degrees/second, attempts to point could be off by 2 degrees

If you attempt to connect to an ASCOM driver with "Continuous Tracking" checked and the ASCOM driver does not support variable rate Moveaxis commands, the software will alert the user and uncheck "Continuous Tracking".

Getting Started

A getting started reference is also available on the [Help] tab of the software.

1. ASCOM drivers must be installed for the mount used. It is not within the scope of this document to cover the installation of ASCOM and drivers. Refer to https://ascom-standards.org. ASCOM drivers are not required when using legacy interfaces.

2. Enter your site information in the [Setup] and [Site] tabs. (see page 5)

3. Download a TLE file containing satellite orbital elements. (see page 10)

4. Verify your computer time is accurate (within a second).

5. On left side bar, connect to your mount. (see page 13)

6. Select a satellite in the [Current Visible Satellites] or [Current and Upcoming Satellite Passes] lists and click [Start Tracking]. (see page 16)

7. Adjust tracking by using the controls under the [Tracking Adjustments] or [Leap Frog] tabs within the [Satellite Tracking] tab. (see page 16)

Setup – Site

1. In the [Setup] tab and the [Site] tab, select a site in the combobox "Select Site". Click [Edit Site].

2.   Enter a site name.

3. Enter the latitude and longitude of your site location, in the format of degrees, minutes, seconds. Values are always entered as positive values, select "N" or "S" for latitude and "W" or "E" for longitude. For example, a site in North America would have "W" for longitude and "N" for latitude, a site in Australia would have "E" for longitude and "S" for latitude. Alternately, you can click the button "Enter Lat/Long in decimal format" and enter the coordinates in the format "dd.dddd".

4. If you have already connected to your mount via ASCOM, you can click the button [Copy Data from Mount GPS] to automatically copy site information to the software (if your ASCOM driver is capable).

5. Enter your elevation (above sea level) in meters. A compass feature on smartphones may have this information for you. The elevation is especially important for calculating satellite transits.

6. Enter "UTC" offset for your location (ie your time zone.) This value is the hours difference from Coordinated Universal Time. The UTC offset for North America would be a negative value. It must also reflect Daylight savings time – the software does NOT automatically adjust for daylight savings. For example, New York would be -5 and during daylight savings be -4. The UTC offset is entered as hours only (not minutes), for example 10.5 instead of 10:30.

7. Optionally, you can enter the minimum elevation limits for your viewing location. This can define any obstructions around you. This is valuable when calculating satellite passes, including the acquisition and loss of signal. The objects in the [Astronomical Objects] lists can also take into account your elevation viewing limits.

8. Click the [Save] button to save your site. It is important that your site parameters are entered accurately in order to predict and view satellite passes. To verify the latitude/longitude entries, click the [Satellites] tab and view the world map. Your site will be displayed with a small red plus sign. Ensure it appears in the correct location. Your mount will also have a UTC or time zone setting and it should match the setting in your site location. When connecting to your mount, SkyTrack will check for the UTC match and warn if they are different (if the ASCOM driver is capable of retrieving the value).

9. It is recommended to keep "Check site UTC with computer time zone" and "Check site UTC with mount setting" enabled. This ensures your computer, mount and SkyTrack settings agree.

Setup – General Setup

Define Acquisition/Loss of Signal
AOS is acquisition (or arrival) of signal. LOS is loss of signal. In SkyTrack, AOS defines when a satellite is above the horizon or viewing limit and illuminated by the sun. LOS is when the satellite is below the horizon or viewing limit and/or when the satellite moves into the earth's shadow and is no longer illuminated by the sun.

You can define AOS and LOS as the horizon (0 degrees elevation) or the viewing limits set in the Site setup. Many of the calculations will take into account these settings such as Satellite pass predictions, the lists of available objects in the [Astronomical Objects] tab, and the predictions in the [Satellite Transits] tab.

Beep when Satellite Becomes AOS
With this option checked when a satellite is selected and is LOS a small beep will sound when the satellite becomes AOS

Alert when AOS in Pop-Out World Maps
When using a pop-out world map, enabling this feature will sound a beep on the arrival of satellite signal.

Ignore Eclipse Status in Pass Calculations
Satellites are not visible (sunlit) when eclipsed by the earth's shadow. You can choose to ignore the eclipse status in pass calculations. This feature is useful for non-visual radio signal tracking.

Define Astronomical Dusk and Optimum Darkness when illuminated Moon
"Define Astronomical Dusk" and "Optimum Darkness when illuminated Moon is" are not related to satellite predictions. These definitions are used in the "Solar System, Stars and Deep Sky Objects" tab. They are used in the "Elevation vs Time" tab for displaying optimum darkness and also when finding the next Dark Period. Default values for astronomical dusk is -18 degrees elevation and -3 degrees elevation for the moon.

Default Days to Calculate Future Satellite Passes and Search Transits
You can choose the default number of days to calculate future satellite passes and transits.

Reset List Column Widths and Clear Flags
"Reset Columns" can be used to reset the widths of the satellite lists and other objects lists. Clear Flags will reset the flagged DSO to an unflagged state.

Dark Mode
Dark screen mode can be turned on or off, or set that it will only come on after sundown for the currently selected site. Two different color sets are available – grey or red theme.

Audit Logging
Audit logging can be enabled/disabled. When enabled, the log file skytrack_log.txt is created in the skytrack folder. Extensive logging can be selected when troubleshooting an issue. You may wish to disable logging when capturing high frame video to minimize hard drive resource use.

Check for Program and Database Updates on Startup
When enabled and an internet connection is available the program will check for updates. If a program update is available it will be displayed in the title bar. Both program and database updates will be displayed under the [Help] tab.

Enable Planetarium Sync with N.I.N.A
Click the checkbox, to enable planetarium sync with N.I.N.A. astrophotography software (https://nighttime-imaging.eu). Port number 3292 is the default port number and cannot be edited.   After selecting an object in the tab "Deep Sky Objects, Stars and Solar System", in N.I.N.A. you can import the object name and coordinates by clicking the "Get coordinates from Planetarium Software" icon. Information is sent using the SAMP messaging protocol.

Selected Satellite TLE Export via TCP
This is a custom feature to export TLE information to another software via TCP through the specified port. When enabled a [TLE Export] button becomes available under the [Satellite Tracking] tab in the [Satellite Data] frame.

Extended parameters in Satellite Pass Export
When enabled extra parameters (altitude, range, latitude, longitude) are included in the satellite pass export file.

Internet Search Option for Astronomical Objects
Under the [Astronomical Objects] tab and [Target Object] frame a button is available to perform an internet search for the selected object. The three choices are a Google search, Google image search or Astrobin image search. (Please note that Astrobin does not endorse SkyTrack and SkyTrack is not certified by Astrobin)

Sky Map Option
The drawing of the sky map under the [Satellite Tracking] tab has a few options. Constellation outlines and/or RA/Dec lines can be enabled. The orientation can be flipped by placing south at the top.

Setup – Global Interface Setup

The global interface settings generally apply to both ASCOM and legacy interfaces with the exception of the ASCOM automatically connect on startup and time-out settings.

Telescope FOV
The telescope FOV (field of view) setting does not affect tracking. It is used to calculate when the object should be in the FOV. This is indicated by the mount location indicator in the sky map turning from a red to a green color. The satellite/mount separation indicator will also turn from red to green when within the field of view. (Note: legacy interfaces will also use the setting from this parameter).

Automatically Connect ASCOM Mount on Startup
Checking "Automatically Connect ASCOM Mount on Startup" will do just that. If checked, when SkyTrack starts up it will automatically attempt to connect to your mount through the ASCOM driver.

ASCOM Connection Time-out
The ASCOM connection time-out defines how long the software will wait for a connection before giving an error message and aborting the connection attempt.

Confirm before Parking Mount
If "Confirm before Parking Mount" is checked, when you click the [Park Mount] button, the software will ask for a confirmation to proceed with the park procedure.

Enable Mount Slew Upper Limit
Check "Enable Mount Slew Upper Limit" if your physical setup requires it, for example to prevent a collision between a camera and a pier or tripod. Enter the upper limit that you want to restrict. Select "Altitude" for an Alt-AZ or "Declination" for an equatorial configuration.

Reverse Manual Slew Keys
The direction of the manual slew keys in the [Manual Slew] frame can be reversed.

Tracking Adjustment Increments
When making tracking adjustments there are fine (single arrow buttons) and coarse (double arrow buttons). In the setup you can define the increment amount adjusted with each click of a button.

Advanced Continuous Tracking Parameters
During continuous tracking SkyTrack calculates the current rate of motion of the satellite being tracked. Adjustments are made to the rate if the mount is not currently centered on the satellite in an attempt to center. The aggression for centering/recentering the satellite can be set. The minimum aggression is used when the satellite is within 1 arcmin of center otherwise the maximum aggression is used. Depending on the characteristics of the mount, settings of 100% may overshoot the satellite – a back and forth oscillation may indicate this and aggression should be decreased. Too low of an aggression will cause prolonged centering of the satellite.

Setup – ASCOM Continuous Interface Setup

The default parameters in the ASCOM continuous interface setup will be adequate for the majority of cases.

Tracking Rate Update Frequency
The tracking rate update frequency is the time interval in which updated tracking rates are sent to the mount. The default is 1500ms. The software will poll the mount for its current position, calculate the current position of the satellite and the satellite's current angular velocity. It will then calculate a new tracking rate so that the satellite should be centered in the field of view at the next rate update. Some mounts may not be able to process the commands quick enough so a longer update frequency may produce better results, if it appears the system is getting overwhelmed. Shorter update frequencies can be tested to see if it results in smoother tracking.

Delay Meridian Flip
When tracking satellites such as the International Space Station, the best views are when the satellite reaches the maximum elevation of its path, which is the closest range to the observer. This often can be near the meridian. With German Equatorial mounts, a meridian flip needs to occur at the meridian. By the time a meridian flip occurs the satellite may have descended considerably.   In this setting you can specify to continue tracking past the meridian for a specified number of degrees before performing a meridian flip. This feature should be used cautiously, ensuring a pier or tripod collision will not occur. It should be noted that the software checks the proximity to the meridian once for each update cycle for the frequency specified in the previous setup parameter. Therefore, allowance for the frequency of meridian checks should be considered when using the slew past meridian feature.

Moveaxis Calibration
Before attempting continuous tracking each ASCOM driver will need to complete a calibration procedure. Unfortunately, ASCOM drivers from different manufacturers do not always interpret the direction of the ASCOM moveaxis commands in the same manner. It is only necessary to run the calibration once. It only determines which way to slew each axis on each side of the meridian. In step number 5, the calibration procedure checks to see if the mount queues mount position coordinates or if it returns near "real time" position coordinates. If step 5 fails, it may still be possible to get reasonably smooth continuous tracking, it simply will not be optimum. SkyTrack will alert the user if a calibration is needed. Re-calibrating is not necessary unless the mount is obviously moving in the wrong direction when tracking and a "Tracking problem detected" error message appears.

Setup – Legacy Interface Setup

Astro-Physics Legacy Interface
The maximum slew rate can be selected. This is the maximum slew rate for "goto" and parking movements.

Sync mode can be selected as "sync" or "recal". See Astro-Physics documentation for definitions.

See "Delay Meridian Flip" under "Setup – ASCOM Continuous Interface Setup". Note the tracking rate update frequency for the AP legacy interface is fixed at 1500ms.

For calibration see "Moveaxis Calibration" under "Setup – ASCOM Continuous Interface Setup".

Note for Astro-Physics mounts, the best satellite tracking configuration is using APCC Pro v1.9.011 or higher and the ASCOM driver. This configuration provides excellent pointing using APCC modelling and APCC supplies "real time" mount location. Using the AP ASCOM driver alone results in poor tracking due to mount position queuing. If APCC Pro is not used, then the next best solution is using the legacy interface.

iOptron Az Mount Pro Legacy Interface
If desired, the tracking rate update frequency can be modified. Please note iOptron motor control firmware version 210320 or higher is required. An option can be selected to prevent cord wrap. If necessary, the mount will unwrap the cords after stopping satellite tracking or before slewing to an astronomical object. Ensure the cord is in an unwrapped position before connected to the mount.

Setup – License Registration

SkyTrack offers a 30 day free trial period. After 30 days the satellite features no longer function, the functions on the [Astronomical Objects] tab will continue to function. After purchasing at https://heavenscape.com, you will receive by email a registration code within 3 business days. If you do not receive your code, please check the spam (or junk) folder of your email, otherwise please contact skytrack@heavenscape.com

Enter your registration code exactly and click [Apply]. The top title bar of the program should now have "Registered" after the version number. Please save your registration code should you require to move SkyTrack to another computer or restore a hard drive.

TLE File

TLE is an acronym for two-line element. It is a specially formatted data file which contains a list of orbital elements of earth orbiting objects for a specific point in time (epoch). In SkyTrack, the TLE data is needed to calculate satellite positions using the SGP4 and SDP4 perturbation models. It is important to download new TLE files frequently for best results. On the [Satellite Tracking] tab, and in the "Satellite Data" frame, the "T+Epoch" displays the age of the TLE data in terms of days. If this parameter is 1.5 days or greater, it will flag with a red background, suggesting to download more current TLE data.

SkyTrack by default, is configured to download several special TLE files from https://Celestrak.com. Special thanks to Dr. T.S. Kelso who gave permission for these direct links. The links may be edited if other internet sources are desired.

Only one TLE file can be loaded and used by SkyTrack at a time. The TLE file "100 Brightest Satellites" is a good file to start with. As the name implies, these satellites are amongst the brightest and most are visible with the naked eye at night.

With an internet connection, click [Download TLE File]. After the download completes, the file will automatically load into SkyTrack and satellite passes are calculated in the "Satellites" tab. If a TLE file already exists by the same name, and is less than 1hr old, a new TLE file will not be downloaded. This is to avoid unnecessary bandwidth use of the Celestrak website. If you wish to change the TLE file to a previously downloaded file, click the [Open File] button and select the file (this step is not necessary during the download process, as a newly downloaded file is automatically opened). Upon opening the TLE file, Skytrack automatically recalculates satellite passes found in the "Satellite" tab.

If there is an error when downloading the TLE file, it may be the internet connection is not available or you do not have write permissions to the SkyTrack folder.

Larger TLE files can be filtered if you are only interested in a certain subset of satellites. Filtering will allow for quicker prediction calculations. A filter file can be created using a text editor such as Notepad. Enter each NORAD numeric designation for the objects desired. Each entry must be followed with a carriage return. Select the filter file and click the "Apply Filter" checkbox to begin filtering. Click the [Clear] button to cancel filtering. A TLE Filter file can also be created in the [Satellite Information] tab.

Satellite Information

The satellite information database is compiled by Union of Concerned Scientists. It used within SkyTrack with permission and is freely distributed at https://www.ucsusa.org/resources/satellite-database.   According to the website, the database is updated three times a year. After installing SkyTrack, the database needs to be downloaded. Under the tabs [TLE/Satellite Information] and [Satellite Information], click the button [Download Information Database]. The "Download Database" frame will show when a newer version is available (if there is internet connectivity).

Upon downloading the database, the list of satellites with available information will display. Double-clicking a satellite or selecting and clicking [Satellite Information] will display detailed information. Note some satellites in a TLE file may not be found in this information database.

To narrow your search for a satellite or group of satellites, you can use the filters on the left side of the window. Check the checkbox to enable the filter and use the corresponding dropdown list to select the desired filter.   Click [Apply] to display the filtered list. Clicking [Clear] will reset the list to the entire database.

After applying and a filtered list is displayed, you can save the results as a "TLE Filter". When saving you will be prompted for a name and folder location. Under the [TLE File] tab, there is an option to load and apply the filter to the current loaded TLE file. For example, if you were interested in only tracking satellites owned by "SpaceX", you could create a filter of "Owner/Operator" of "SpaceX". Save the filter file, load it in the "TLE File" tab and subsequently any downloaded TLE file would only display SpaceX satellites. Upon saving a TLE Filter file, the user is prompted if they wish to immediately apply the filter against the loaded TLE file.

Satellite information detail can also be displayed from the [TLE File] tab and the [Satellite Tracking] tab. In both cases, select a satellite from a list and click the button [Satellite Information].

Note that correction and additions to the database can be submitted to the Union of Concerned Scientists at SatelliteData@ucsusa.org . The author of SkyTrack does not maintain the database.

Identify Satellites

Under the tabs [TLE/Satellite Information] and [Identify Satellite] the user can identify a satellite which they inadvertently observed or imaged. This feature may also be useful to identify what time(s) you may want to avoid imaging an astronomical object if you want to avoid numerous satellite streaks.

Select a range of dates to be searched. Clicking the [Astronomical Dusk] button will change the "From" time to astronomical dusk.

Select an object or set of coordinates for the search, also specify the approximate degrees of the field of view.

A few filters can be applied to the search – for sunlit satellites only (which can cause light streaks in an image), whether to include geostationary images or to only include satellites with a certain name or partial name.

Click [Find Possible Satellite(s)] and a list of satellites will appear, indicating whether or not they are sunlit, the angular separation from the center of the specified field of view and the satellite name.

During a search, it can be cancelled by clicking [Cancel Find].

Other

The [ASCOM Compatibility] tab displays data after connecting to the ASCOM driver. Some ASCOM features are required for satellite tracking, some are optional for certain features, and others are planned to be used in future versions.

Under the [Coordinates Utilities] tab, the "Coordinates Conversion" frame allows for the conversion of right ascension and declination coordinates. Enter the coordinates in one of two formats, select the conversion required and click the [Convert] button. If you are converting to Azimuth/Altitude a date and time must be specified. Click the [Clear] button to reset and start over with new entries.

In the "Angular Separation" frame, enter two sets of coordinates to calculate the angular separation of the objects. Click the [Calculate] button to see the results.

Connection to your Telescope Mount and ASCOM

SkyTrack offers two different ways to communicate with your telescope mount: ASCOM or legacy interfaces for a limited number of telescopes.

ASCOM is an acronym for **AS**tronomy **C**ommon **O**bject **M**odel. It provides a standard interface to various astronomy devices and in the case of SkyTrack, to the telescope mount. To download and install ASCOM and the drivers for your mount, visit https://ascom-standards.org. (This help documentation does not describe the setup of ASCOM and related drivers)

With ASCOM and the related ASCOM drivers installed and configured, click the "ASCOM" tab in the bottom left corner of the main Skytrack dialog. Click the [Choose] button, which then displays the "ASCOM Telescope Chooser" dialog. Select the driver for your telescope mount and click [Ok]. When running SkyTrack subsequent times, it will remember the ASCOM driver previously chosen.

Click the checkbox "Continuous Tracking" for smooth continuous tracking (if mount supports necessary features) or leave unchecked for "leap frog" style of tracking. This option must be selected before connecting to mount. If you wish to change your selection, the mount must be disconnected. After an ASCOM driver and Continuous Tracking option is chosen, click the [Connect Mount] button to connect. If communication is successful, the [Connect Mount] button changes to [Disconnect Mount] and the "Connected" LED button (small red rectangle) illuminates to a brighter red color. The current pointing position of the mount displays in the "Mount Position" frame in the upper left area of the main SkyTrack dialog. Several other controls related to the mount will become active.

If you choose to connect via the legacy interfaces, some features/controls may not be available and the mount position is not displayed. (The NexStar and Astro-Physics legacy interfaces support all SkyTrack features)

Please note before attempting to track satellites, your mount must be aligned as you would for normal viewing. An accurate alignment is essential.

Satellites

On the [Satellites Tracking] tab there are three different satellite pass lists:

"Current Visible Satellites" List

The "Current Visible Satellites" lists all currently visible satellites (except if "Include All (no filters)" is checked, then all satellites in the TLE file are listed). **This is the only list that includes geostationary satellites**. Current cardinal direction and elevation (including whether the satellite is **A**scending or **D**escending) is listed but other satellite pass information is not listed. This list does not automatically refresh. Click the [Refresh List] button to update.

"Current and Upcoming Satellite Passes" List

This list contains all the current and upcoming satellite passes according to the filters set. The data in the list continuously updates (only for the original calculated passes- new passes are not added). If a satellite has already reached its AOS (acquisition of signal) time or maximum elevation time, the corresponding data field will be blank. When a satellite reaches its LOS time, it is deleted from the list. Note that AOS and LOS are calculated according to the parameters in the [Setup] tab, defined as at the horizon or at the site specific viewing limits. A satellite eclipsed by the earth's shadow is considered LOS. After modifying a filter, the [Recalculate] button must be clicked to refresh the list with the chosen filters. Geostationary satellites do not have a "pass" and are not included in this list. Use the "Current Visible Satellites" for geostationary satellites. If a large TLE file is loaded and broad filters are chosen, the software limits the number of passes listed to 2000 passes.

"Satellite Future Pass Predictions" List

This list predicts future satellite passes for one selected satellite. The pass predictions in the "Current and Upcoming Satellite Passes" list are limited to 24 hours whereas this list can predict several days in the future. Clicking on a satellite in this list, will display the pass in the maps and "Satellite Data" frame starting at the AOS time. Text with a red background in the world map will display the date and time of the predicted pass as it is not the current date/time. When a pass is predicted several days out, as the date/time of the pass approaches an updated TLE file should be downloaded and the pass recalculated.

Maps and Satellite Data

Upon clicking a satellite in one of the three satellite lists, data will appear in the "Satellite Data" frame and the pass will appear on the world map and the sky map (if above the horizon).

The **satellite data** consists of:
- satellite name
- NORAD (**Nor**th American **A**erospace **D**efence) ID is a sequential 5 digit number assigned for all man-made objects orbiting earth. The minimum object size for the catalog is 10cm in diameter. Objects that orbit for only a short period of time are not catalogued.
- Year is the year of launch followed by a sequential number counting the objects launched in that year.
- T+Epoch, is the age of the orbital elements in the loaded TLE file expressed in days. When T+Epoch is greater than 1.5 days, the age is displayed with a red background as a reminder to consider downloading a more recent TLE file.
- RA,Dec, Azimuth, Elevation are the coordinates of the current position of the satellite.
- Altitude is the height in kilometers of the satellite to the earth's surface (at sea level)
- Range is the distance in kilometers from the satellite to the observer's location.
- Velocity is the speed at which the satellite is moving in its orbit expressed in kilometers/hour.
- AOS is acquisition (or arrival) of signal, when the satellite is above the viewing limits (or horizon depending on setup) and is illuminated by the sun.
- LOS is loss of signal, when the satellite goes below the viewing limits (or horizon depending on setup) or enters the earth's eclipse and is no longer illuminated.
  Note these are modified definitions of AOS and LOS for visual tracking. Normally, AOS and LOS would not be defined by the illuminated/eclipsed status of satellite.
- The last data field specifies whether the satellite is ascending/descending/below horizon, its cardinal direction and illuminated/eclipsed state.

  When the satellite is viewable, the values in the "Satellite Data" frame are displayed with a green font, otherwise a red font is used.

The **star map** shows the common stars and constellations as seen from the site selected. If the selected satellite is above the horizon, its path is displayed with a yellow, orange or gray line.   Yellow indicates where the satellite is about to travel, whereas, orange indicates where the satellite has just travelled. Gray indicates the satellite will be/was in an eclipsed state, whereas yellow/orange indicates it will be/was illuminated by the sun. A small solid blue circle indicates the current position of the satellite. When a geostationary satellite is selected, there is no path displayed. When connected to the telescope mount (ASCOM only), a red or green outlined circle indicates the current pointing position of the mount. If the mount has reached its target position the circle is green, otherwise it is red. The edge of the

map is the horizon, not the defined viewing limits. The sky map also displays the meridian and if the satellite will cross the meridian, the time to meridian is displayed.

The **world map** displays the current path of satellite selected. The satellite path colors are similar to the star map. In addition, the world map indicates the area on the earth that the satellite is visible with a red oval line. The red line indicates visibility down to the horizon and does not account for the illuminated/eclipsed state of the satellite. A small red "+" sign indicates the location of the selected site.

Tracking Satellites

Setup must be completed before attempting to track a satellite (see page 5). A current TLE file must be downloaded (see page 10). Your computer time must be as accurate as possible.

Connect to your mount through an ASCOM driver or a legacy interface option. (see page 11)

Select a satellite in the "Current Visible Satellites" or "Current and Upcoming Satellite Passes" list. The satellite should be above the horizon and above any view limits established in the setup before tracking can be initiated (with some mount interfaces if the satellite is still at LOS, the mount will slew to point where the satellite will become AOS and wait for the satellite to arrive at which point tracking will begin). If you are using a German equatorial mount, check the sky map for time to meridian if the satellite will cross the meridian. If the satellite is close to meridian, you may wish to delay the start of tracking until it crosses.

Click the "Start Satellite Tracking" button to start tracking. The mount will slew ahead of the current satellite position to attempt to intercept it.

Leap Frog Tracking
See the description of leap frog tracking (see page 3).

In the "Leap Frog" tab, you can adjust "Leap Ahead" which is how many seconds ahead of the moving satellite that the mount will point to. "FOV Drift" is the number of seconds the mount will wait for the satellite to pass through the field of view, before it "leaps ahead" again. When starting out, it is best to set both of these parameters towards larger numbers. This will give more leeway in the timing. Once the satellite is located, you can decrease the values to allow for more viewing time.

Timing and Perpendicular Axis Adjustments
Timing is critical. To adjust for timing, click the coarse (double arrow) or fine (single arrow) buttons in the "Tracking Adjustments" tab. By default, the timing buttons are pointing left and right. This will adjust the mount pointing along the

path of the satellite. It can also compensate for any inaccuracies of the set computer time.

Perpendicular axis adjustment is not needed if the mount is well aligned and has excellent pointing accuracy. This will adjust pointing perpendicular to the path of the moving satellite. It may be useful for attempting to center the satellite on the chip of a camera. By default, the perpendicular axis buttons are pointing up and down.

Depending on the orientation of the telescope and camera (or eyepiece), you may wish to swap the timing and perpendicular controls to make adjustments more intuitive. Each set of controls can have the direction of adjustments reversed as well. Click the pop-out button to create a stay-on-top small window with the adjustment controls. This is useful to move on top of a video capture window to center the satellite in the field of view. A joystick or gamepad can also be used to make the tracking adjustments. This method is useful when making adjustments at a telescope eyepiece.

Between each tracking event, the leap frog parameters and tracking adjustment settings are maintained. Clicking the "0" button in the center of the tracking adjustment controls will zero the timing and perpendicular settings at any time.

Clicking on the [Mouse/Keyboard Tool] button opens a dialog which offers an alternative method to adjust both the "Timing Adjustment" and "Perpendicular Adjustment" settings.   Adjustments can be made with either the keyboard or by using the computer mouse.   Using the "mouse mode", a right-click starts and ends the adjustment mode, or alternatively the [End] key also starts or ends the adjustment mode. Perpendicular adjustments may be opposite of the viewed effects, in which case click "Reverse alignment axis".

Satellite tracking will automatically stop at LOS but also depends on the setting of the checkbox "Stop Tracking when Satellite is Eclipsed".   If unchecked, tracking will continue as the satellite moves into the earth's shadow and will not stop until the satellite reaches the view limits or horizon. Satellite tracking can be stopped at any time by clicking the [Stop Satellite Tracking] button (Note when starting tracking the [Start Satellite Tracking] button is renamed to [Stop Satellite Tracking]) or by clicking the red [Stop] button in the "Manual Slew" frame on the left-hand side of the main dialog. Tracking may also be stopped if the mount reaches an upper limit of altitude or declination as defined in the "Setup" tab.

When tracking geostationary satellites, the mount slews to the satellite position and sidereal tracking is turned off because the satellite remains stationary in the sky relative to the site. Leap frog parameters and other adjustments have no effect.

Satellite Transits

The [Satellite Transits] tab is used to calculate transits of any satellite but most interestingly of the International Space Station (ISS) with either the moon, sun (or any of the planets). Angular separation is the distance from the center of the sun or moon disc to the satellite. A transit occurs when the angular separation is less the sun or moon's radius.

A specific site can be calculated for, or check "All Sites" to calculate for all sites defined in Setup.

Choose a range of dates to include in the calculations. Choosing too far into the future may not produce accurate results as orbits change or are adjusted over time. It is always best to download an updated TLE file and recalculate nearer to the anticipated event.

Click the "Include Near Transits" checkbox, to include in the list of events a pass in which a near transit occurs. The maximum angular separation of near transits can be defined.

If an event is found, clicking on the event will display the details in the "Event Details" list and the sun or moon with the satellite path are shown in the graphic box. If lunar transits are chosen, the moon phase and its orientation are also shown.

After selecting a transit event and displaying the details, you can find the optimum location to view the transit (ie less separation between the satellite and the astronomical object). SkyTrack can calculate a transit line in which any point on the line is an optimum location for a zero degree separation transit. The software creates a ".kml" file describing the line, the time of transit, elevation and cardinal direction. It is recommended to install Google Earth Pro for desktops to view the transit line on a map.

Select a near transit after the initial transit search. Click [View Transit Line with Google Earth Desktop]. The transit line is calculated and written to a ".kml" file and displayed in Google Earth (if installed and "Automatically view with Google Earth" is checked). A red line is displayed, any point on the red line will be a location for an optimum transit. If high precision is required, pick a location on the map (along the red line) in which you wish to view the transit from. Note the displayed elevation in Google Earth for the desired location. In SkyTrack, enter the elevation in the text box "Elevation" in the "Satellite Transit" tab. Recalculate the transit line by clicking [View Transit Line with Google Earth Desktop] again. The entire transit line is calculated at the specified elevation. The extra precision of specifying the exact elevation is usually not needed for solar and lunar transitions but is required for successful transits with planets. You can specify the location and name of the ".kml" file. You can also Google Earth Web to load the ".kml" file and display the transit

line. I find Google Earth for desktops is preferable. Remember when going to a transit location, always double check the location with the most current TLE file possible, as satellite orbits do change.

In Google Earth, you can use the yellow pushpin icon called "Add Placemark" to select a point along the transit line. The placemark will be displayed on the list of placemarks underneath the placemarks generated by SkyTrack. Right-click on the new placemark and select "Save Place As". Save the placemark as a ".kml" file.   In SkyTrack, you can set up a new site for the transit and import the coordinates from the saved ".kml" file. Note that the elevation will still have to be manually entered.

SkyTrack can create a calendar event for the transit in the form of a ".ics" file. The calendar event will display the latitude and longitude of the site selected in the search for transit dialog. For more details of searching for transits view the videos in the SkyTrack YouTube channel.

Astronomical Objects

The [Astronomical Objects] tab is for viewing space objects other than satellites. It is not meant to be a substitute for planetarium software but rather a tool to quickly establish the best time to view or photograph a common object.

Calculation Date and Time

All calculations on this tab are dependent on the date and time in the "Calculation Date and Time" frame. In the bottom of this frame, the actual calculation date and time is displayed.   Calculations can be based on the current computer date/time or a specified date and time. (Note this date/time setting does not affect satellite calculations in the other tabs).   When specifying a date and time, clicking the "Set time to astronomical dusk" checkbox will automatically change the time to "astronomical dusk" for the selected date.

Astronomical dusk is the beginning of nighttime when the last shimmer of sunlight disappears. By default, SkyTrack defines astronomical dusk when the sun is 18 degrees below the horizon. This value can be modified under the "Setup" tab if desired. Likewise, an illuminated moon can light up the night sky. Optimum darkness is defined by default when the illuminated moon is 3 degrees below the horizon in addition to astronomical dusk. The default of 3 degrees can also be modified under the "Setup" tab.

Find Dark Period

The "Find Dark Period" frame is useful to find the next time period were there is optimal darkness at the selected site. You can select the date to start searching from, if any amount of moon illumination is allowable, and the period in hours that you desire. The system will find the next occurrence that matches your parameters and the date and time is automatically displayed in the "Calculation Date and Time" frame. All object lists are automatically recalculated.

Elevation vs Time Graph

Clicking on any object, in one of the three object lists will graph the object's elevation in the "Elevation vs Time" frame. The purpose of the graph is to display the optimal time period for viewing or photographing an object. The background of the graph is blue for daytime, black for night and various shades of blue for twilight. The graph line, which is the selected object's elevation graphed over time, is white when sunlit, yellow when moonlit, red when below the site's defined elevation limits, and green when in optimal darkness. Vertical green dotted lines going down from the graphed line to the time axis shows the range of times that the object is in optimal darkness. A yellow band on the time axis shows the time period of the illuminated moon.

Object Lists

There are five object tabs which show the objects above the viewing limits for the date and time of calculation (shown in the "Calculation Date and Time" frame) unless "Show … at all elevations" is checked. Included in the list is the name of object, cardinal direction and elevation in degrees. Note that the data does not continuously update, the button [Refresh all Lists] must be clicked to update the data.

For comets and asteroids, current orbital elements should be used by clicking the download button for each. If for a session, comets and asteroids are not of interest then delete the elements for quicker recalculation of the object lists.

The "Deep Sky Objects – Elevations" list displays the elevation of the object over four time periods. This is to assist in determining how many hours of photographing would be possible. The time period increments can be selected. Various filters can be used to narrow down the list of objects. Objects can be flagged as a favorite (indicated by an asterisk).

The objects in the lists in this version of SkyTrack are hard-coded and cannot be edited. If you wish to graph or slew to a target not included, enter the coordinates in the frame (on the left side of the main dialog) called "Target Coordinates". Click the [Graph] button and the user coordinates object will graph. Coordinates can be

entered at topocentric or J2000. J2000 is a common epoch for libraries of astronomical objects.

When an object is selected from a list, its name and coordinates are displayed in the "Target" frame. If the mount is connected, clicking "Slew to Object" will slew the mount to the object. When the mount is pointing at the object, the text in the "Target" frame will be displayed in green, otherwise red text is used. Once the object is reached, it can be centered in the FOV, and clicking the [Sync] button will perform an alignment synchronization with the mount. Note this will modify the mount alignment.   This feature is only available if your ASCOM driver supports it. (On the "Utilities" tab, in the "ASCOM Capabilities" frame see "CanSync"). Clicking the "Internet Search" button will do a Google search for the selected object if internet connectivity is available.

Moon Phases, Rise and Set

In the [Solar System] tab, the "Moon Phases, Rise and Set" displays the moon phases, and other moon data for the selected date and time in the "Calculation Date and Time" frame.   Rise and set times are based on the horizon, not the viewing limits.

Pointing Model

Using a camera and plate solving software SkyTrack has the ability to create a pointing model for a specific satellite pass. This feature does not replace the typical alignment procedure of your mount but is used to enhance pointing accuracy. While it may not be practical to create a model for every satellite tracked, it is more useful for a high interest object like the International Space Station, especially when recording with a small sensor camera.

SkyTrack creates two subfolders called "Images" and "Models" where the images and model data are respectively saved.

Camera and Plate Solve Setup

Camera Setup
Install the ASCOM drivers for your camera and select the ASCOM driver by clicking [Choose Driver].

The default binning is "1x1", you might choose another option if your camera has a high resolution sensor chip (to speed up image download times).

Set the exposure for the plate solve images. The default is 6 seconds. If plate solving is unsuccessful try different values. When troubleshooting plate solving you may wish to view the .fits files (under the "Images" subdirectory) to see the number of

stars resolved and if they are a well rounded shape. Various free .fits file viewers can be found online.

Set the gain for your camera. After connecting to the camera the gain range for the specific camera will be displayed.

If the connected camera has cooling capabilities, cooling can be enabled to a specific temperature. Cooling can prevent excessive noise which may aid in plate solving performance.

Two different plate solvers can be used with SkyTrack – ASTAP and/or ANSVR.

ASTAP Setup
ASTAP plate solving software can be downloaded at
https://www.hnsky.org/astap.htm   In addition to the program software a star database (H17 or H18) must also be installed. The ASTAP path must be defined for SkyTrack to run "astap.exe". The default path for ASTAP is assumed in SkyTrack and the SkyTrack setting only needs to be modified if you chose a different path during the ASTAP installation. The maximum stars setting has a default off 500 and normally does not need to modified. If your camera has numerous hot pixels and there is difficulty in plate solving images you can use the "Maximum Star Size" setting to attempt to exclude hot pixels.

ANSVR Setup
Astrometry.net Local plate solver can be downloaded at
https://adgsoftware.com/ansvr/ Follow the instructions on the download page to install the program and the star database indexes. If you have plenty of hard drive space it is best to select the entire range of indexes as a common issue when using ANSVR is not having the appropriate indexes for your setup installed. Like ASTAP, SkyTrack needs to be configured for the location of the ANSVR install. It assumes the default location, if you changed the default during the ANSVR installation then the new path must be configured in SkyTrack. The pixel size settings and telescope focal length are important settings with ANSVR. The "Image Scale Allowance" setting defines the tolerance in which those settings may vary. A tighter (smaller) setting will result in slightly faster solve times but if your settings vary more than the allowance then plate solve failures can occur. 20% is default setting in SkyTrack. The image can also be downsampled by ANSVR before analyzing. 2 is the default setting in SkyTrack. Experiment with this value when troubleshooting unsuccessful plate solving.

Plate Solve - General Setup
One or both of the above plate solvers can be used. The ideal setup is to use one as the primary plate solver and the other as secondary. SkyTrack will first attempt to plate solve an image with the primary solver. If the primary solver fails, it will then attempt to solve with the secondary plate solver. Generally, ASTAP is preferred as the primary plate solver because of its speed.

The telescope focal length is important information for calculating the image scale that both solvers require for effective solving. Reducers or barlows must be accounted for in this value. For example, if the telescope has a focal length of 800mm and a 2x barlow is used then enter a focal length of 1600mm. If you click [Capture Test Image] and [Solve Test Image] the calculated focal length may appear in the solve results message box. If it differs significantly then enter the value in the focal length field.

The camera pixel size must be entered accurately for the proper image scale calculation. Depending on the camera ASCOM driver functionality the value may automatically populate when connecting to the camera otherwise refer to the camera specifications from the manufacturer.

The plate solve time-out default is 60s.

"Settle time after slew" is the time in seconds that the system will pause after completing a slew and before starting to expose an image during the model building process. This allows for any vibration or flexure to settle before imaging which may otherwise result in a blurred or streaked star pattern and subsequently resulting in poor plate solving performance.

Creating a Satellite Path Pointing Model

Creating a satellite path pointing model begins with selecting a specific satellite and a specific pass and generating points along the pass path to plate solve and calculate pointing inaccuracies.

In the frame "Define Points to Solve", select how far apart (in arcmins) the points that you want to create for solving and the starting/ending elevations that you expect to track the satellite.

Under the [Satellite Tracking] tab and either the [Current and Upcoming Satellite Passes] or [Satellite Future Pass Predictions] tabs, select a satellite pass to create points to solve by clicking the button [Create Model Pass Points]. The points are generated and the [Satellite Path Pointing Model] tab is displayed. If you wish at this point, you can redefine the parameters under "Define Points to Solve" and click the button [Re-apply to current satellite path model points] to generate new points.

When the mount and camera are connected you can begin to solve the points by clicking [Solve All Pass Points]. For each point, the mount will slew to, settle, image and solve. The process can be aborted at any time by clicking [Abort].   If you wish to re-solve click the point and click [Solve Selected Pass Point].

If "Verify Precision" is enabled, the point will be slewed to and solved again using the information from the first plate solve. In the list the result in arcminutes will be

displayed under the "Corrected Error" column. This represents the amount of pointing error to be expected during satellite tracking with the model enabled.

The model is automatically saved in the subfolder called "Models".   Several models can be created ahead of time. To load a previous model click [Load Model]. To activate a model click "Enable Model". When a model is enabled it will appear in the left hand section in the frame "Pointing Model". The model file name uses the convention "N"{NORAD number}"_T"{HH:MM:SS of satellite AOS}"_"{site name}.pmdl

After creating a model(s) remember to disconnect the camera if using another software to capture images/video. Cameras cannot be shared between more than one programs and will usually results in errors. Avoid connecting to the camera simultaneously between two software.

Remember the model only enhances pointing accuracy and does not replace the requirement to use your mount's alignment procedure.   The model becomes invalid upon moving/adjusting your mount or realignment using the mount alignment procedure.   While the model improves pointing it has no effect on the timing setup of the satellite. You will still need to adjust for timing along the path which is a factor of the computer time accuracy and the TLE file accuracy.   If pointing still appears inaccurate for a satellite pass it may due to inaccurate or outdated TLE parameters.

Eventually you may wish to delete old models in the SkyTrack "Models" subfolder as SkyTrack has no maintenance features for old models. The "Images" subfolder does not require maintenance as image files are overwritten for each pass solve so image files do not accumulate.

Other Frames on the Main Screen

Mount Position

The "Mount Position" frame displays the current coordinates of the mount and the local sidereal time. **Red** "LEDs" illuminate (change to a brighter red color) when the mount is tracking or slewing. Note that "Tracking" refers to sidereal tracking, not tracking a satellite.

Manual Slew

The "Manual Slew" frame allows manual slewing of the mount. The red [Stop] button will also abort satellite tracking.

Target Coordinates

The current target coordinates are displayed in this frame. Coordinates can manually be entered in either topocentric or J2000 epoch. The mount can be slewed to the target coordinates by clicking the [Slew to Target] button or graphed in the "Solar System, Stars and Deep Sky Objects" tab by clicking the [Graph] button.

Note, when connecting to the mount, SkyTrack determines which coordinate epoch the mount uses. It will automatically convert coordinates to the correct epoch when sending coordinates to the mount through the ASCOM driver.

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Email: skytrack@heavenscape.com   Website: https://heavenscape.com

YouTube Channel: https://www.youtube.com/channel/UCz0Dpacz9h-Ru85Pv6qmtag/videos

NORAD SGP4/SDP4 orbital models code was derived from Turbo Pascal code by Dr T.S. Kelso. TLE downloads are courtesy of Celestrak.com and used with permission.

Various calculations from Astronomical Algorithms Second Edition 1998 by Jean Meeus

The Satellite Information database is compiled by Union of Concerned Scientists. It used within SkyTrack permission and is freely distributed at https://www.ucsusa.org/resources/satellite-database

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