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 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

Audit.txt   - contains audit information for troubleshooting. This file is initialized each time the program executed. The previous file is copied to audit_old.txt.

.tle/.txt   - downloaded TLE files containing satellite orbital elements

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.

Satellite Tracking Methods

SkyTrack uses two methods of satellite tracking – "Leap Frog" and "Continuous" tracking. In the current version, mounts using ASCOM track using the "Leap Frog" method only. Some 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 (expressed in seconds) and drift wait time can be configured.

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).

Currently, many ASCOM compatible mounts do not support variable slew rates.   To effectively facilitate continuous tracking a few capabilities are required;

- ASCOM methods "SetRightAscensionRate" and "SetDeclinationRate" are available
- When issuing ASCOM "GetRightAscension" and "GetDeclination", the driver must return live time position data. Some drivers only update the position at timed intervals. For example, if this 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
- ASCOM method "SetPierSide". For GEM mounts, when slewing with variable tracking rates, meridian flip commands must be issued by the software

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" tab. (see page 5)

3. Download a TLE file containing satellite orbital elements. (see page 7)

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

5. On left side bar, connect to your mount. (see page 8)

6. Select a satellite in the "Current Visible Satellites" or "Current and Upcoming Satellite Passes" lists and click "Start Tracking". (see page 11)

7. Adjust tracking by moving the sliders in the "Leap Frog Parameters", "Timing Adjustment" and "Alignment Adjustment" frames. (see page 11)

Setup – Site

1. In the [Setup] tab and within the "Site" frame, 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.

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.

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 "Solar System, Stars and Deep Sky 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).

Setup – Miscellaneous

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.

1. 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 "Solar System, Stars and Deep Sky Objects" tab, and the predictions in the "ISS Transits" tab.

2. You can choose to ignore the eclipse status in pass calculations. This feature is useful for non-visual radio signal tracking.

3. 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.

4. 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.

5. "Rapid Leap Mode – Delay between Slews" is not used with the current version.

6. 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.

7. "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.

8. You can choose the default number of days to calculate future satellite passes and ISS transits.

9.   "Reset Columns" can be used to reset the widths of the satellite lists and other objects lists. Reset Deep Sky Favorites will reset the flagged DSO to the SkyTrack default.

Setup – Product Registration

SkyTrack offers a 30 day trial period. After 30 days the satellite features no longer function, the functions on the "Solar System, Stars and Deep Sky 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 [Satellites] 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.

Utilities

The "Utilities" tab consists of three different frames.

The "ASCOM Compatibility" 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.

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.

After an ASCOM driver 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 be come 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 legacy interface supports 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" 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 **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 8). Your computer time must be as accurate as possible.

Connect to your mount through an ASCOM driver or a legacy interface option. (see page 8)

Select a satellite in the "Current Visible Satellites" or "Current and Upcoming Satellite Passes" list. The satellite must be above the horizon and above any view limits established in the setup before tracking can be initiated.

Click the "Start Satellite Tracking" button to start tracking. The mount will slew ahead of the current satellite position to attempt to intercept it. See the description of leap frog tracking (see page 5).

In the "Leap Frog Parameters" frame, 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 is critical. To adjust for timing, move the sliders in the "Timing Adjustment" frame. This will adjust the mount pointing along the path of the satellite. It can also compensate for any inaccuracies of the set computer time.

"Alignment 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.

Between each tracking event, the leap frog parameters and timing adjustment settings are maintained. The alignment adjustment will reset to zero each time tracking is initiated.

Clicking on the [Timing/Align Tool] button opens a dialog which offers an alternative method to adjust both the "Timing Adjustment" and "Alignment Adjustment" sliders.   Adjustments can be made with either the keyboard or a joystick, 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. If using a joystick, it may be intuitive to orient the joystick so that the left and right movement of the stick aligns with the path that the satellite is moving. Alignment 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.

ISS Transits

The "ISS Transits" tab is used to calculate transits of the International Space Station (ISS) with either the moon or the sun. If ISS is not present in the currently loaded TLE file, the function is disabled. Angular separation is the distance from the center of the sun or moon disc to ISS. 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.

This tool is best suited for permanent viewing locations such as an observatory or a backyard. If your setup is easily portable, https://transit-finder.com is an excellent tool as it demonstrates the optimum location for a given ISS pass and possible transit. It may be surprising how relocating even a short distance (still in terms of miles or kilometers) will change the angular separation of the transit.

Solar System, Stars and Deep Sky Objects

The "Solar System, Stars and Deep Sky Objects" tab is for viewing other 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 four 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

The four object lists show the objects above the viewing limits for the date and time of calculation (shown in the "Calculation Date and Time" frame).   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.

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

The "Moon Phases, Rise and Set" frame 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.

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

NORAD SGP4/SDP4 orbital models code was derived from Turbo Pascal code by Dr T.S. Kelso

Various calculations from Astronomical Algorithms Second Edition 1998 by Jean Meeus