

## 8 Sateph User's manual

This document is a manual to the program Sateph, software designed to assist to space debris and satellites optical measurements. The Graphic User Interface (GUI) with all program functions is discussed.

### 8.1 Program installation

In the beginning whole Sateph directory called 'Sateph 2' should be copied from CD into the wanted directory on the hard disk. At least Java Runtime Environment (JRE) version 1.5 must be present on given computer. Program can be run by file called 'SatEph\_2.2.jar', no installation is necessary. Program is tested only for Windows operating systems. After the program is executed, user is welcomed by main window plotted in Figure 8.1.

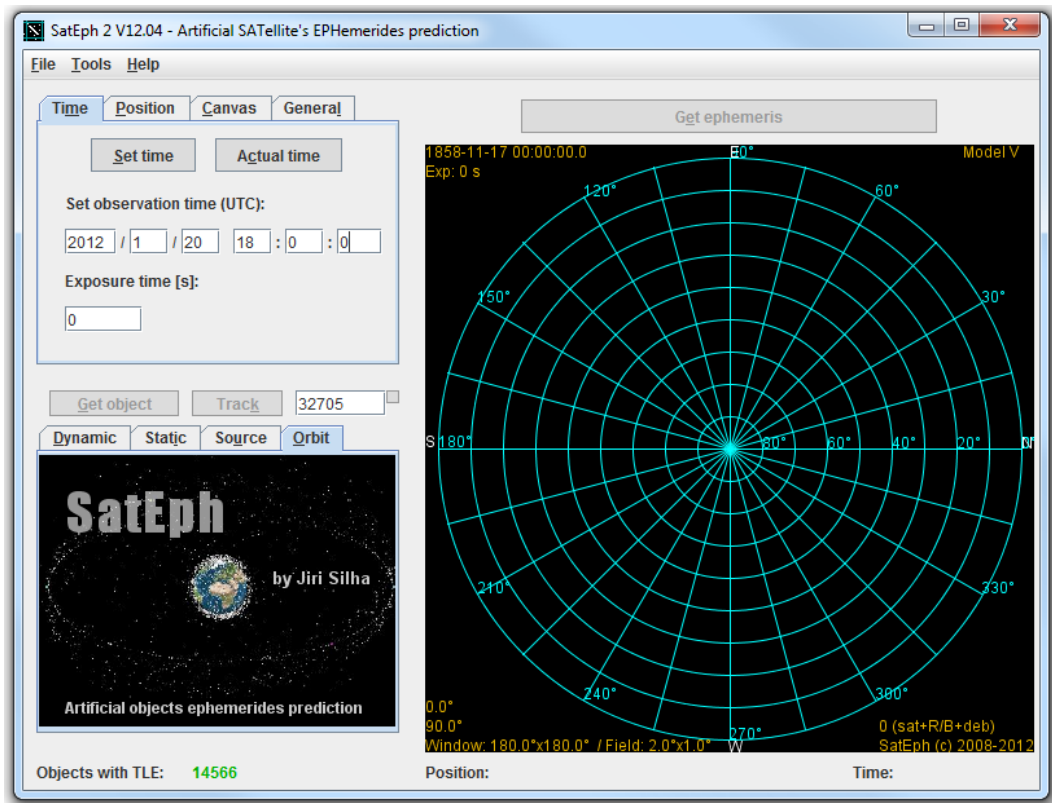


Figure 8.1 – Sateph program's main window. This is welcome version of main window right after the program is executed and when program is not active yet.

Structure of program is separated into the four major windows which are plotted in Figure 8.2. The main window (plotted in Figure 8.1), image settings window, identification

window and HD display. All windows with their functions are described in detail in the following sections.

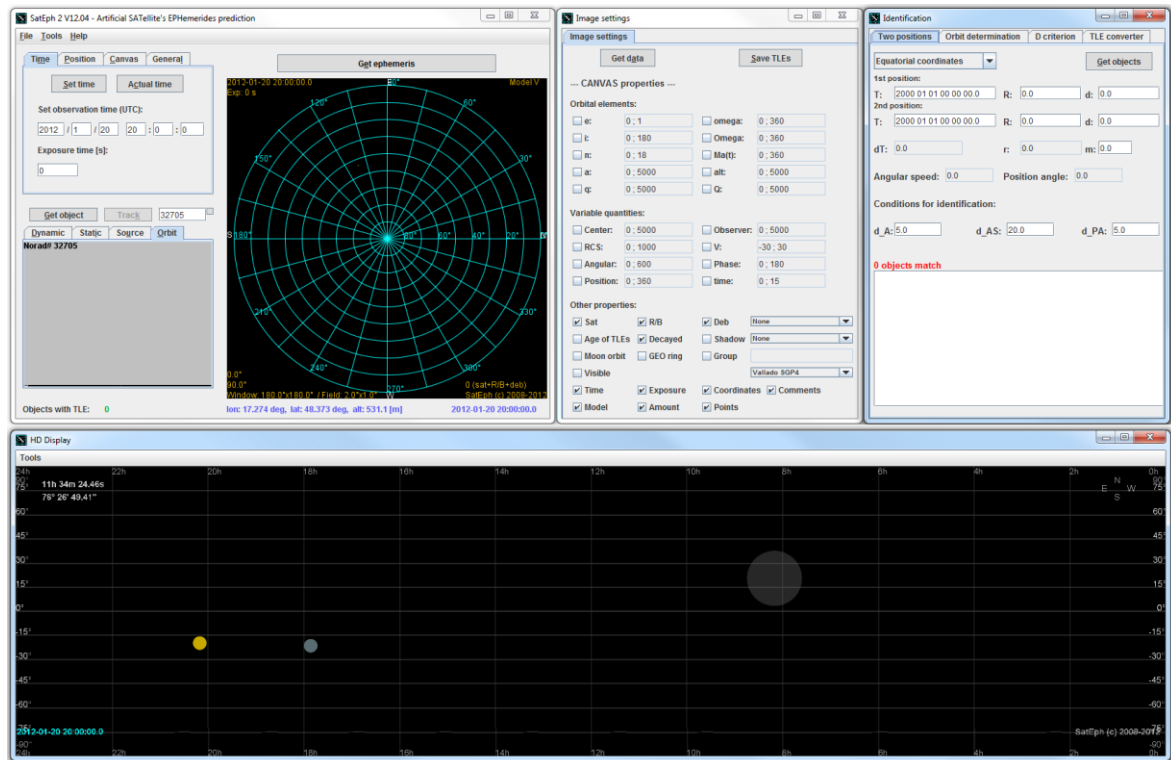


Figure 8.2 – Sateph program's four major windows. Main window (upper left corner), image settings window (up in the middle), identification window (upper corner right) and HD display window (down) are plotted.

## 8.2 Main window

Purpose of main window is to manage input and output data into the program and from the program, set the graphical representation of data to the user and manage other additional windows. Main window can be separated into several parts as is marked in Figure 8.3. On left upper corner is situated menu item (marked by red circle) which provides to user ability to load data such as TLEs or save data such as selected satellite's ephemerides data or plotted image. Settings menu (marked by green rectangle) obtains four submenus, 'Time' to set observation time, 'Position' to set the observer geodetic position, 'Canvas' to set the canvas properties and 'General' which is carrying basic information about loaded data. The information about selected object are displayed (marked by blue rectangle) in data menu. There is 'Dynamic' submenu with objects actual data such as equatorial and horizontal coordinates for selected observation time, in 'Static' submenu the additional information about selected object are displayed such as its international designator, type or source, in 'Source' the object's source data are plotted such as its

loaded TLE and in ‘Orbit’ submenu the quick look on object’s orbit is plotted. On the canvas, the ephemerides of objects are plotted.

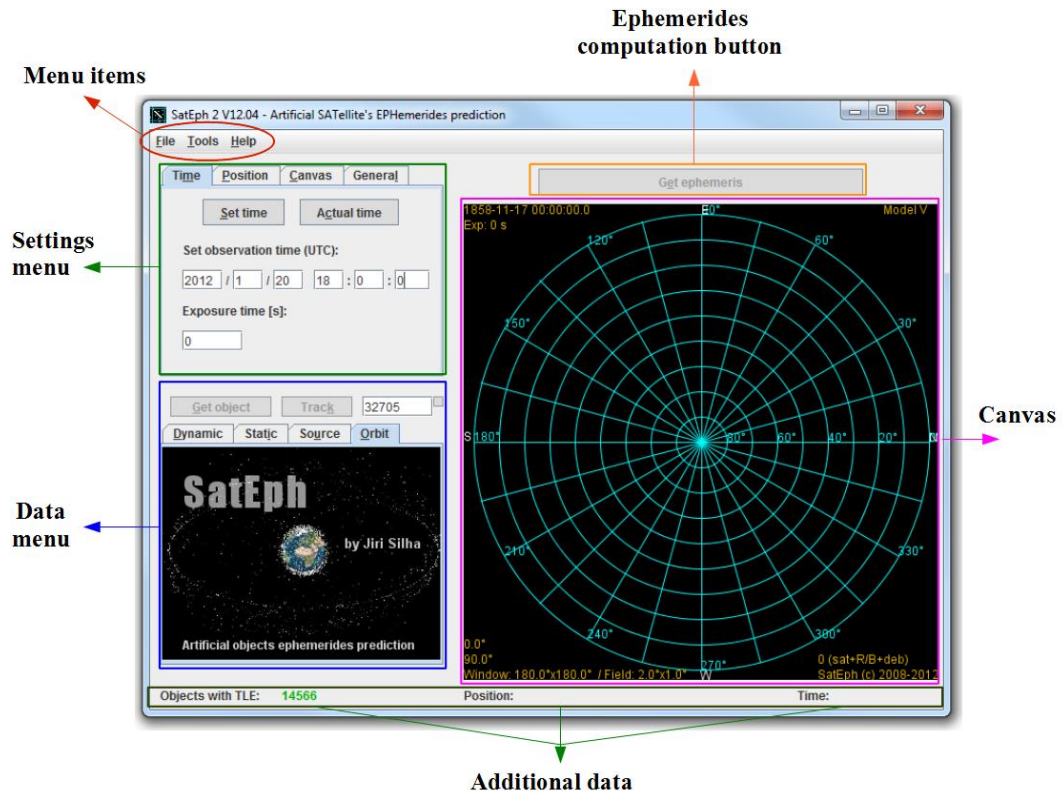


Figure 8.3 - Main window with its menu items (red circle), settings menu (green rectangle), data menu (blue rectangle), computational button ‘Get ephemerides’ (orange rectangle), canvas (pink rectangle) and additional data (dark green rectangle).

To get objects ephemerides, program Sateph has to load orbital elements first. If there is a file called ‘tle.txt’ in Sateph’s subdirectory ‘Sateph 2\data’ and this file contains valid form of TLEs data, these data will be loaded into the program during its start up section. One can verify how many objects have loaded TLE values by looking into the left lower corner of the main window (Figure 8.3 left, additional data). To activate the main window two values must be set in settings menu window, the observation time in section ‘Time’ by clicking on button ‘Set time’ (Figure 8.4 left) and observer geodetic position in section ‘Position’ by clicking on button ‘Set position’ (Figure 8.4 right). Now user is able to start computation of ephemerides by clicking active ephemerides computation button plotted in Figure 8.5. After the computation is done, the canvas window will repaint and the computed ephemerides will plot on it (Figure 8.6). In case that ephemerides computation button is becoming red, new data are loaded into the program and new ephemerides must be calculated again. All main window items are further discussed in the next sections.

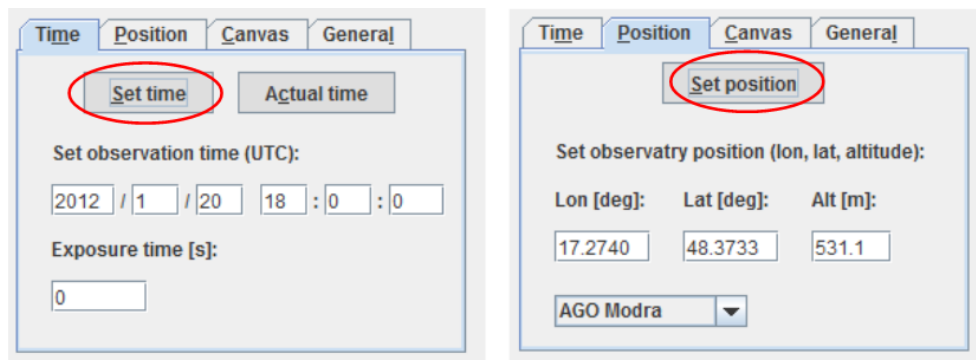


Figure 8.4 - Submenus 'Time' (left) and 'Position' (right) are part of setting menu on main window. The observation time and observer geodetic position must be set to get option for ephemerides computation.

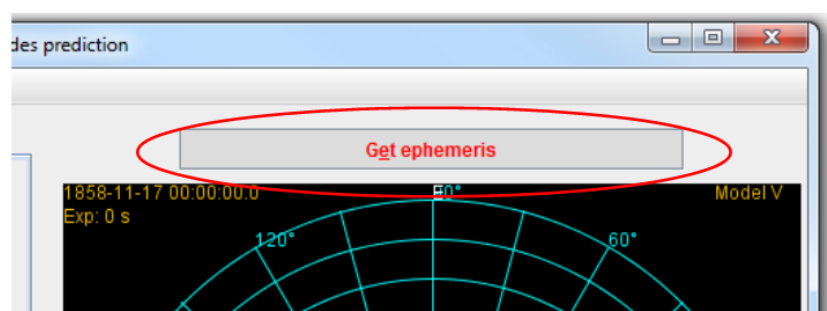


Figure 8.5 - Get ephemerides button. When program has set observation time, observer geodetic position values and TLE data are loaded into the program's memory one can use this button to get ephemerides of all objects with available TLE which will be plotted on canvas.

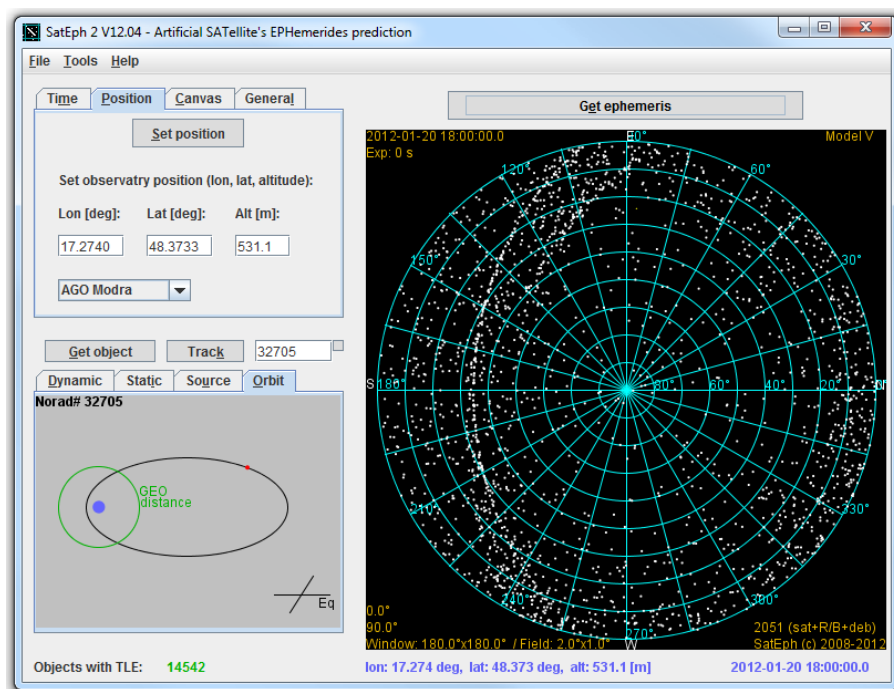


Figure 8.6 - Main window after the 'Get ephemerides' button is clicked and the ephemerides are calculated and then plotted on canvas.

## 8.2.1 Menu items

Menu items plotted in Figure 8.7 have following functions:

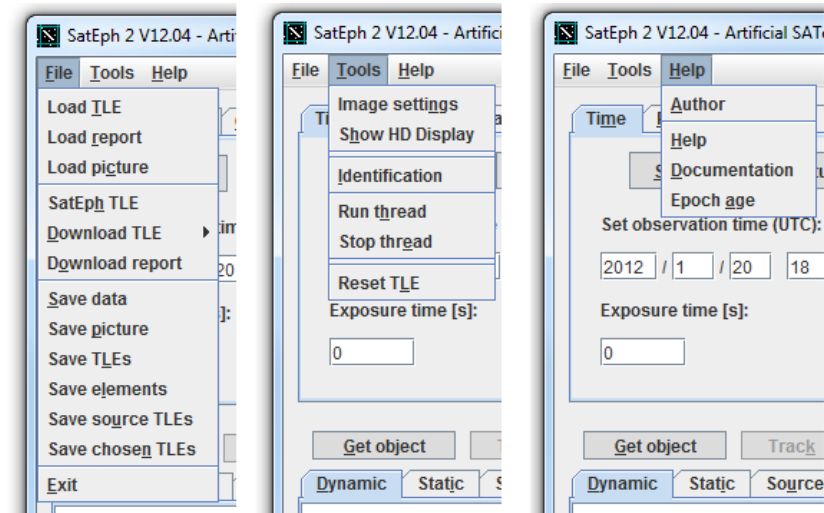


Figure 8.7 - Menu items situated in main window. The 'File', 'Tools' and 'Help' menu items are plotted.

**‘File / Load TLE’** – If the user wants to load specific TLE file situated on the disk this menu item can be used. There are two valid forms of TLE data format for Sateph, the classical TLE (Figure 8.8) and three lines TLE with zero line, which usually contains object’s name. Program does not distinguish between files suffixes (.dat, .tle, .txt etc.).

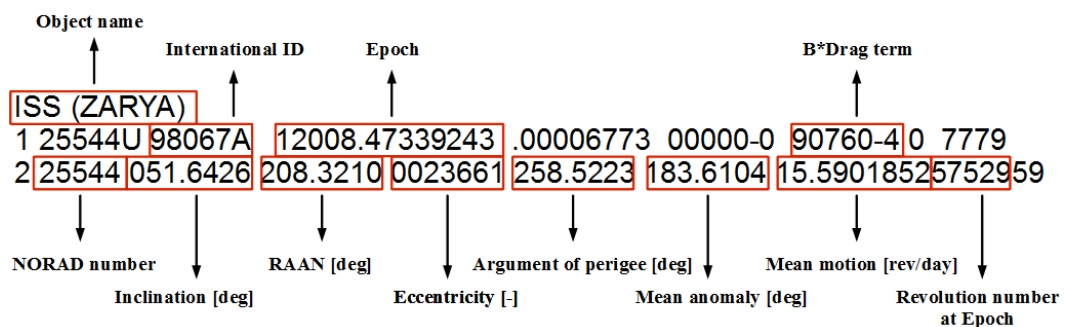


Figure 8.8 - Example of TLE format of orbital elements of International Space Station.

**‘File / Load report’** – This item can be used to directly load valid ‘ssr.txt’ file provided by [www.space-track.org](http://www.space-track.org) from the disk. This file contains object’s name, source, mean radar cross section (RCS) etc. If there is file called ‘ssr.txt’ in Sateph subdirectory ‘Sateph 2\data’ and this file has valid form it will be loaded into the program memory during its start up section. For valid format of ‘ssr.txt’ see [www.space-rack.org](http://www.space-rack.org).

**‘File / Load picture’** – This item provide user ability to load image into the program memory and use it or display it later on canvas.

**‘File / SatEph TLE’** – Thanks to this item the TLEs will be loaded into the program from file ‘tle.txt’ situated in subdirectory ‘Sateph 2\data’.

**‘File / Download TLE’** – This item is set to download TLE data from the internet sources, save them on the disk, unzip them and then load data into the program. The public catalogue can be downloaded and then read by selecting item **‘File / Download TLE / Download TLE general’**, the elements from supplemental source [www.celestrak.com](http://www.celestrak.com) can be downloaded and then read by selecting item **‘File / Download TLE / Download TLE Kelso’** and all available TLEs can be downloaded and then read by selecting item **File / Download TLE / Download TLE all’**.

**‘File / Download report’** – Thanks to this item the ‘ssr.txt’ file will be downloaded from the internet and then read by the program.

**‘File / Save data’** – Using this item saves the selected objects ephemerides into the subdirectory ‘Sateph 2\save’. Created ‘DAT’ file’s name will consist from selected object’s NORAD number and the ephemerides start time. In Figure 8.9 example of ephemerides is plotted. Source file of this data had name ‘#55570\_090316\_221148.dat’.

```
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
----- NORAD# 55570 -----

VFMO090316
1 55570U 00000A 09075.92485624 .000000000 00000-0 00000-0 0 0000
2 55570 023.1226 124.7120 2091291 233.3682 190.9894 00.66290009 01

Object int ID:      2000-000A
Start time:         2009-03-16 22:11:48.0 (UTC)
Start time:         54906.924861111111 days (MJD)
Observatory:        17.274 deg, 48.3733 deg, 531.1 m
Exp time:           10 s
Visual mag:         16.3 ; 16.3
Standard mag:       5.5
Angular speed:      6.316 arcmin/min
Position angle:     76.603 deg
```

Date (UTC)	Az [deg]	h [deg]	R. A. [deg]	dec [deg]	Phase [deg]	obs. r. [km]	Shadow
2009-03-16 22:11:48.0	145.81974	54.87096	184.50892	17.21612	17.549	61776.72	false
2009-03-16 22:11:49.0	145.82312	54.87225	184.51072	17.21655	17.550	61776.568	false
2009-03-16 22:11:50.0	145.82649	54.87353	184.51248	17.21697	17.551	61776.424	false
2009-03-16 22:11:51.0	145.82987	54.87482	184.51428	17.2174	17.552	61776.272	false
2009-03-16 22:11:52.0	145.83324	54.8761	184.51606	17.21782	17.553	61776.12	false
2009-03-16 22:11:53.0	145.83662	54.87739	184.51784	17.21825	17.554	61775.972	false
2009-03-16 22:11:54.0	145.83999	54.87867	184.51962	17.21867	17.556	61775.82	false
2009-03-16 22:11:55.0	145.84337	54.87996	184.5214	17.2191	17.557	61775.672	false
2009-03-16 22:11:56.0	145.84675	54.88124	184.5232	17.21952	17.558	61775.52	false
2009-03-16 22:11:57.0	145.85012	54.88253	184.52496	17.21994	17.559	61775.372	false
2009-03-16 22:11:58.0	145.8535	54.88381	184.52676	17.22037	17.560	61775.22	false

SatEph

Figure 8.9 - Example of ephemerides generated by program Sateph. There are ephemerides of unknown object VFMO090316 accidentally tracked in March 2009 at Astronomical and Geophysical Observatory FMPI CU, Modra (AGO). Elements were determinate by program Sateph.

**‘File / Save picture’** – Using this item will save ‘BMP’ image generated by canvas into the subdirectory ‘Sateph 2\save’. In case that HD display is showed also image generated by this canvas will be saved on disk.

**‘File / Save TLEs’** – Program will save all TLEs which are loaded into the program’s memory. Data will be saved into the ‘TXT’ file called ‘SatEph\_tle.txt’ situated in ‘Sateph 2\data’.

**‘File / Save elements’** – Program will save orbital elements of objects chosen by criteria selected by user into the ‘TXT’ file called ‘elements.txt’ situated in ‘Sateph 2\data’. This format is different that TLE format, easier to use. Data are stored in rows starting with object’s NORAD number, then semi-major axis [km], eccentricity, inclination [°], argument of perigee [°], right ascension of ascending node [°], perigee altitude [km], apogee altitude [km] and period [min].

**‘File / Save source TLEs’** – This item will save TLEs loaded in program’s memory into the file ‘tle.txt’ situated in subdirectory ‘Sateph 2\data’.

**‘File / Save chosen TLEs’** – This item will save TLEs chosen by criteria selected by user into the file ‘SatEph\_chosen\_tle.txt’ situated in subdirectory ‘Sateph 2\data’.

**‘File / Exit’** – This item will close the program.

**‘Tools / Image settings’** – This item will open settings window.

**‘Tools / Show HD Display’** – This item will open window HD display.

**‘Tools / Identification’** – This item will open identification window.

**‘Tools / Run thread’** – This item will run real-time simulation. The ephemerides of the objects will be calculated and repaint automatically every few seconds.

**‘Tools / Stop thread’** – This item will stop real-time simulation.

**‘Tools / Reset TLE’** – All objects data will be reset to zero values.

**‘Help / Author’** – Basic information about author of the program.

**‘Help / Help’** – The ‘PDF’ file with Sateph User’s manual will open.

**‘Help / Documentation’** – The program’s JAVA documentation will open.



**‘Help / Epoch age’** – The color-dependent age of epoch will be displayed.

## 8.2.2 Settings menu window

This menu is separated into the four sections (Figure 8.10), the ‘Time’, ‘Position’, ‘Canvas’ and ‘General’.

The figure displays four panels of the settings menu, each with a tabbed interface (Time, Position, Canvas, General).

- Time Panel:** Contains buttons 'Set time' and 'Actual time'. It has input fields for 'Set observation time (UTC):' (year: 2012, month: 1, day: 20, hour: 18, minute: 0, second: 0) and 'Exposure time [s]:' (0).
- Position Panel:** Contains a 'Set position' button. It has input fields for 'Set observatry position (lon, lat, altitude):' (Lon [deg]: 17.2740, Lat [deg]: 48.3733, Alt [m]: 531.1) and a dropdown menu showing 'AGO Modra'.
- Canvas Panel:** Contains buttons 'Repaint', 'Rotate', and a dropdown menu 'Hor'. It has input fields for 'Az:' (0), 'h:' (90), 's:' (180), 'w:' (2), and 'h:' (1). It also has checkboxes for 'Grid' (checked), 'Field', 'Picture', and 'Norad'.
- General Panel:** Displays a list of statistics: 'Date of sat. report: January 23, 2012', 'Total no. of objects: 38084', 'No. of objects on Earth orbit: 15700(\*)', 'Objects with TLE: 14542', 'Objects with TLE (Kelso): 0(\*\*)', and 'Largest NORAD#: 38095'. It also includes footnotes: '(\*) Some of objects can be already destroyed!' and '(\*\*) Some objects can be downloaded more than once!'.

Figure 8.10 - Settings menu sections. The 'Time', 'Position', 'Canvas' and 'General' sections are plotted.

**Section ‘Time’** – In this section user can set observation time. Time must be set in Coordinated Universal Time (UTC). Values for measurement time as year, month, day, hour, minute and second must be input separately in given text-fields. By clicking on button ‘Set time’, the set values will be loaded into the program’s memory. Actual set time will be displayed in the right lower corner of the main window as is plotted in Figure 8.6 (the additional data). Except the measurement time user can also set the exposure time by setting value into the text-field ‘Exposure time [s]’. Using button ‘Actual time’ will set all time values into the system actual time.

**Section ‘Position’** – In this section the observer geodetic position can be set which consists from geodetic longitude ‘Lon [deg]:’, latitude ‘Lat [deg]:’ and altitude ‘Alt [m]:’. By clicking on button ‘Set position’, the set values will be loaded into the program’s memory. Actual set position will be displayed in the middle lower part of the main window as is plotted in Figure 8.6 (the additional data). By selecting combo-box on the left lower part of



the window, user can use default values for three selected observatories Astronomical and Geophysical Observatory FMPI CU, Modra ‘AGO Modra’, Las Campanas Observatory ‘LCO Magellan’ and Cerro Tololo Inter-American Observatory ‘CTIO MODEST’. After observatory is chosen, the button ‘Set position’ must be clicked.

Section ‘**Canvas**’ – This section is dedicated to the canvas properties. User can choose how the ephemerides data should be plotted. There are three type of coordinate systems that user can choose, the horizontal ‘Hor’, equatorial ‘Eq(N)’ and ‘Eq(S)’ and Cartesians ‘Eq(3D)’ (Figure 8.11 and Figure 8.12).

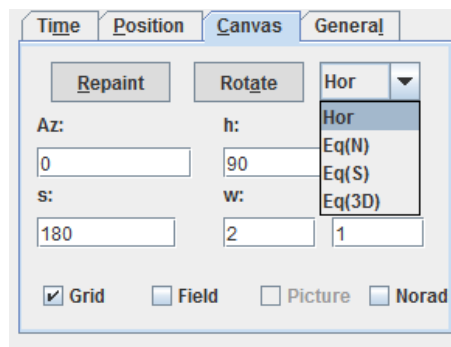


Figure 8.11 - Option for choosing coordinates for canvas in section 'Canvas' in settings window.

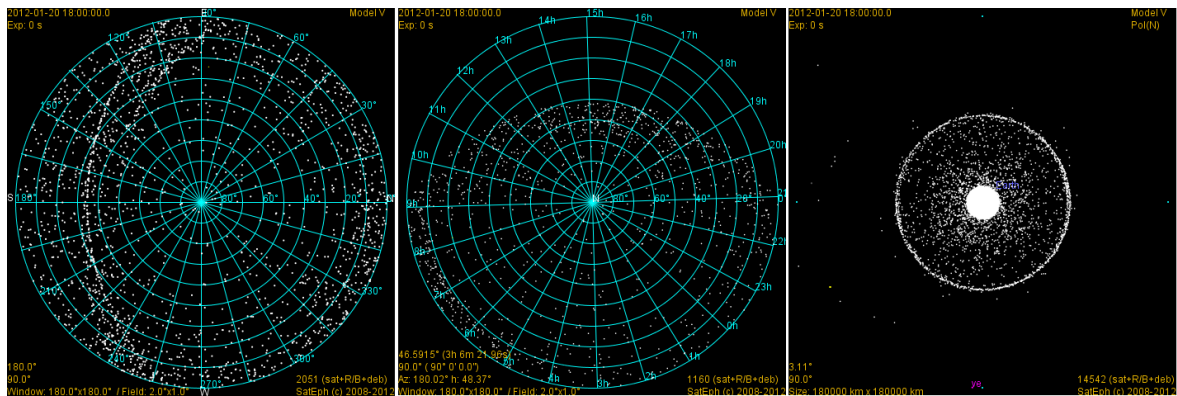


Figure 8.12 - Types of canvas plots are displayed. There are horizontal coordinates (Hor) (left), equatorial coordinates (Eq(N)) (middle) and Cartesian coordinates (Eq(3D)) (right) plotted on the figure.

Option ‘**Hor**’ – When this type of coordinates are chosen, user can set the center of field of view (FOV) in horizontal coordinates by setting values in text-fields ‘Az:’ and ‘h:’. There are valid any values for azimuth and values (0°; 90°) for elevation. Objects ephemerides will be plotted in horizontal coordinates. By clicking button ‘Repaint’ the set values will be read and then the canvas will be repaint. By clicking button ‘Rotate’ whole canvas will rotate by 10 degrees in clock-counter direction. By setting values into the text-

field 's:' the canvas will zoom to given size. The FOV can be set by setting values 'w:' and 'h:' (lower text-field) and by marking the check-box 'Field'. By marking check-box 'Grid' the grid will be plotted on the canvas and by marking check-box 'Norad' the NORAD number of plotted objects will appear next to the objects positions.

**Example** - In Figure 8.13 is an example of plot in horizontal coordinates. By setting values 'Az:' to  $110.37^\circ$  and 'h:' (upper text-field) to  $58.03^\circ$ , the center of FOV will be used as a center of canvas. Program accepts two formats for degree values for 'Az:' and 'h:' text-fields, e.g. 'Az:' can be set as  $110.37^\circ$  but also  $110^\circ 22' 1''$  (see Figure 8.13). By setting values 's:' to  $5^\circ$ , 'w:' to  $1.5^\circ$  and 'h:' to  $1^\circ$  the canvas will have size of  $5 \times 5$  degrees and FOV (plotted as white rectangle) will have size  $1.5 \times 1$  degrees. To plot the FOV the check-box, 'Field' must be marked. By marking the check-box 'Norad' the NORAD number will appear next to the object's position, in this case 8195. When exposure time is set in section 'Time' user is able to see ephemerides of chosen object for given exposure time (plotted as white line) and is able to identify the object's motion direction (marked by red arrow).

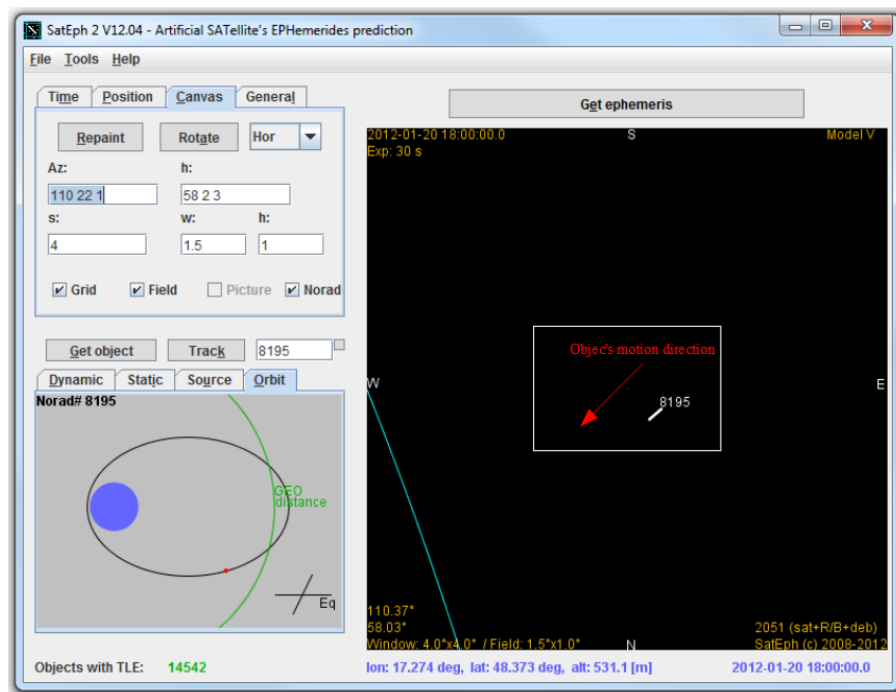


Figure 8.13 – Example of canvas plot in horizontal coordinates.

Option '**Eq(N)**' – This option together with '**Eq(S)**' will plot ephemerides in equatorial coordinates. Similar as with option 'Hor' user can choose center of the FOV by setting values for text-fields 'R.A:' and 'dec:' in hours angles for right ascension and in degrees

for declination. Once the image is loaded through the menu item 'Load picture' and the check-boxes 'Field' and 'Picture' are marked the image will be plotted in FOV rectangle.

**Example** – in Figure 8.13 an example of equatorial coordinates plot is displayed. As is visible from the figure, the center of FOV can be set in following form: hour, arc-minutes, arc-seconds -  $2^{\text{h}} 6^{\text{m}} 12.68^{\text{s}}$  or in decimal format 2.10352. Declination is set in degrees and can be set as  $52^{\circ} 1' 48.36''$  or  $52.0301^{\circ}$ . On canvas also picture which was loaded into the program's memory is plotted. This picture would display after the check-box 'Picture' will be marked.

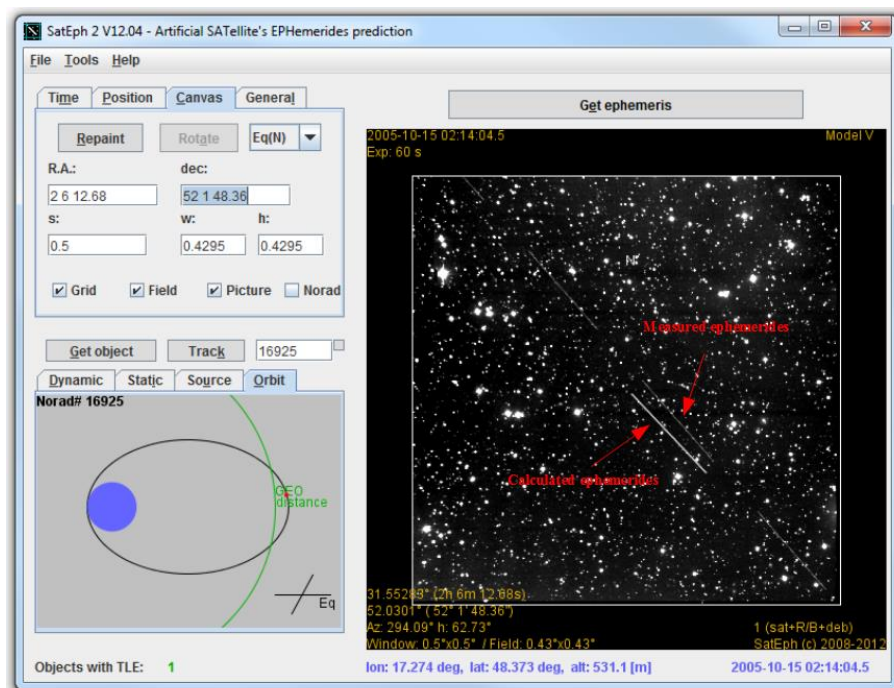


Figure 8.14 - Example of canvas plot in equatorial coordinates. Picture loaded into the program's memory through menu item 'Load picture' is also plotted.

In Figure 8.14 the exposure image is plotted. Object displayed on image was accidentally tracked during observations at AGO in 2005. Object was later identified as an already decayed rocket body NORAD 16923. As is visible from the figure there is a discrepancy between measured and calculated ephemerides. This is caused most probably by object's TLE old epoch.

**Option 'Eq(3D)'** – This option will plot all object in three dimensional plot (3D plot), where user can choose from which point of view the data should be displayed. This plot is designed for presentation purposes. To set the point of view user must set values in text-fields 'alpha:' which is geocentric right ascension measured from the vernal equinox and

“delta:” which is declination measured in positive and negative direction from the equator to the poles. Also distance from the Earth’s center can be set by set value into the text-field ‘r:’. Distance must be set in [km]. There is an example of 3D plot in Figure 8.13. User can change the point of view by several options, using the function in ‘Canvas’ section, using the buttons situated on to the canvas (blue buttons in the right upper corner) and by using the mouse.

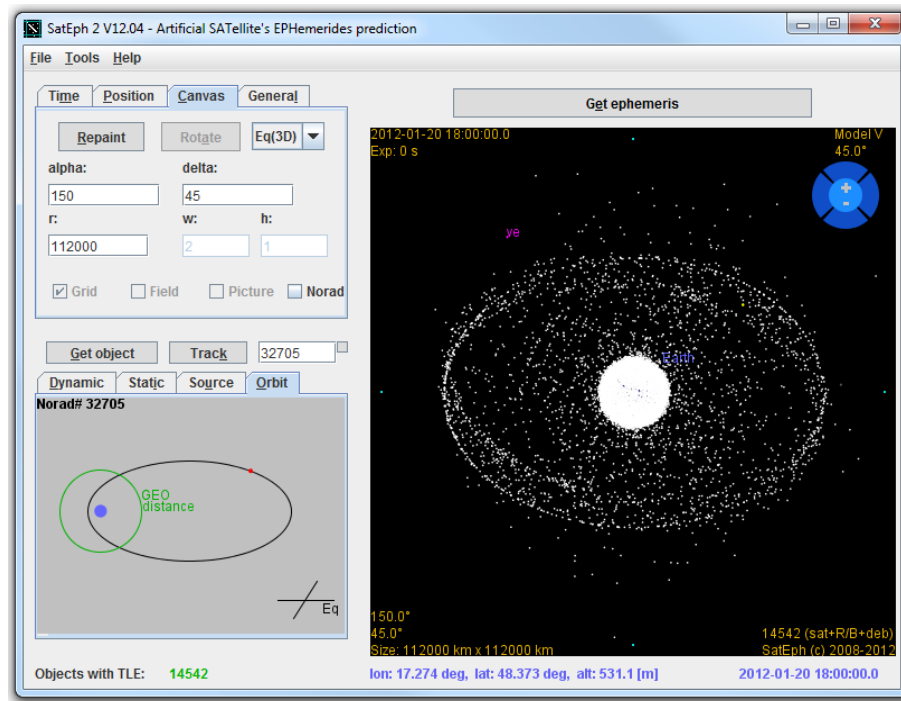


Figure 8.15 - Example of canvas plot in three dimensional coordinate system.

Section ‘**General**’ – In this section basic information about loaded data are listed. Data such as how many objects do have TLE loaded, how many objects are in the ‘ssr.txt’ file or from which date the ‘ssr.txt’ file comes from. See also the right lower image in Figure 8.10.

### 8.2.3 Data menu window

This menu sections are plotted in Figure 8.16. This menu consists from ‘Get object’ functions (buttons and text-field marked by red circle on the figure) and four sections the ‘Dynamic’, ‘Static’, ‘Source’ and ‘Orbit’. This whole menu window is dedicated to the selected object’s data, its actual ephemerides, TLE, orbit etc. To obtain wanted object’s data, the user has to set its NORAD number into the text-field marked by red circle plotted in Figure 8.13 and then click the ‘Get object’ button. In the figure number 25544 is set

which is a NORAD number of International Space Station (ISS). Data menu window sections are further discussed.

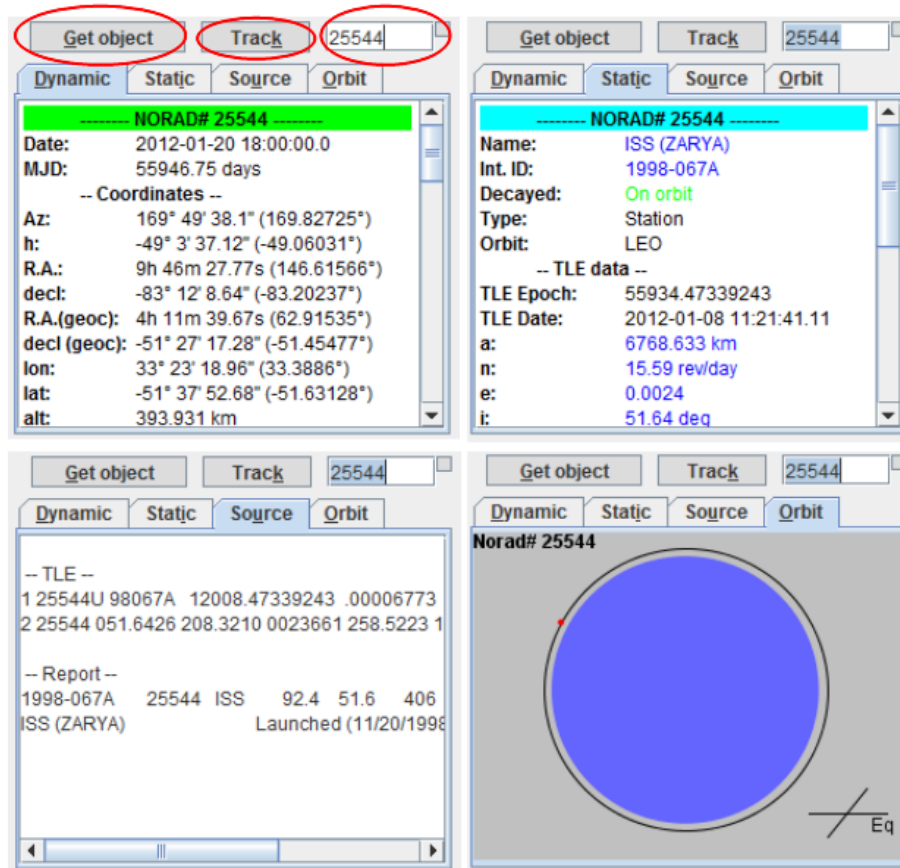


Figure 8.16 - Data menu sections. The 'Dynamic', 'Static', 'Source' and 'Orbit' sections are plotted. On the top of every section also 'Get object' function which consists from buttons 'Get object' and 'Track' with text-field is plotted.

**Section ‘Dynamic’** – In this section all variable data fixed to the given object and set measurement time are plotted. User can find data which are summarized in following table:

Variable	Comments
<i>NORAD number</i>	Satellite's NORAD number
<i>Date</i>	Measurement date and time
<i>MJD</i>	Measurement date and time in modified Julian date [days]
<i>Az: &amp; h</i>	Satellite's horizontal coordinates
<i>R.A. &amp; decl</i>	Satellite's equatorial coordinates
<i>R.A.(geoc) &amp; decl (geoc)</i>	Satellite's geocentric equatorial coordinates
<i>lon, lat, alt</i>	Satellite's geodetic coordinates
<i>Epoch</i>	Difference between satellite's TLE epoch and measurement time [days]
<i>Moving &amp; static mag</i>	Brightness of object according to the observer
<i>Angular</i>	Angular velocities in equatorial and horizontal coordinates

<i>Pos angle</i>	Position angle of satellite
<i>Is visible &amp; shadow</i>	Satellite's position according to the observer and the Earth's shadow
<i>Observer &amp; center</i>	Distance between satellite - observer and satellite – Earth's center [km]
<i>Velocity</i>	Geocentric velocity of the satellite [km/s]
<i>Phase</i>	Phase angle between sun-satellite-observer
<i>M(date)</i>	Mean anomaly for measurement time
<i>Sun</i>	Sun coordinates
<i>Antihelion</i>	Anti-solar point coordinates
<i>Moon</i>	Moon coordinates

Section '**Static**' – In this section all available variable data about selected object that program is using as inputs are listed. User can find data which are summarized in following table:

<b>Variable</b>	<b>Comments</b>
<i>NORAD number</i>	Satellite's NORAD number
<i>Name</i>	Satellite's name
<i>Int.ID.</i>	Satellite's international designator
<i>Decayed</i>	Information whether or not satellite is still on orbit
<i>Type</i>	Type of satellite. Station, Spacecraft - Sat, rocket body R/B and other debris Deb
<i>Orbit</i>	The satellite's type of orbit. LEO, MEO, GEO and super-GEO
<i>TLE Epoch</i>	Epoch of satellite's TLE in modified Julian date [days]
<i>TLE date</i>	Epoch of satellite's TLE
<i>a, n, e, i, Omega, omega,</i>	Orbital elements obtained from satellite's TLE. Semi-major axis, mean motion, eccentricity, inclination, RAAN, argument of perigee, mean anomaly, period
<i>M(epoch), P</i>	
<i>q x Q, q x Q alt, mean altitude</i>	Orbital perigee and apogee, perigee and apogee altitudes and mean altitude
<i>Epoch no.</i>	Number of satellite's revolutions around the Earth according to TLE epoch
<i>B*Drag</i>	B*Drag coefficient used in TLE
<i>RCS</i>	Mean value of radar cross section obtained from file 'ssr.txt'
<i>St mag</i>	Standard magnitude of satellite calculated from RCS value
<i>Source</i>	Country or company of satellite's origin
<i>Launched</i>	Satellite's launched date

Section '**Source**' – In this section are plotted TLE of object which was used for ephemerides computation and data obtained from file 'ssr.txt'. Both these data are source information listed in sections 'Dynamic' and 'Static'.

Section '**Orbit**' – In this section is displayed object's orbit.

#### 8.2.4 Canvas window

Canvas window was discussed in section 8.2.2 Settings menu window.

### 8.3 Image settings window

This window is activated by menu item 'Tools / Image settings'. The main purpose of this window is to set plot conditions for canvas. Also using selected criteria user is able to save elements by using button 'Save TLEs' or by using menu items 'Save elements' and 'Save chosen TLEs'. Image settings window is plotted in Figure 8.17. To get variables which are set in this window the button 'Get data' must be used.

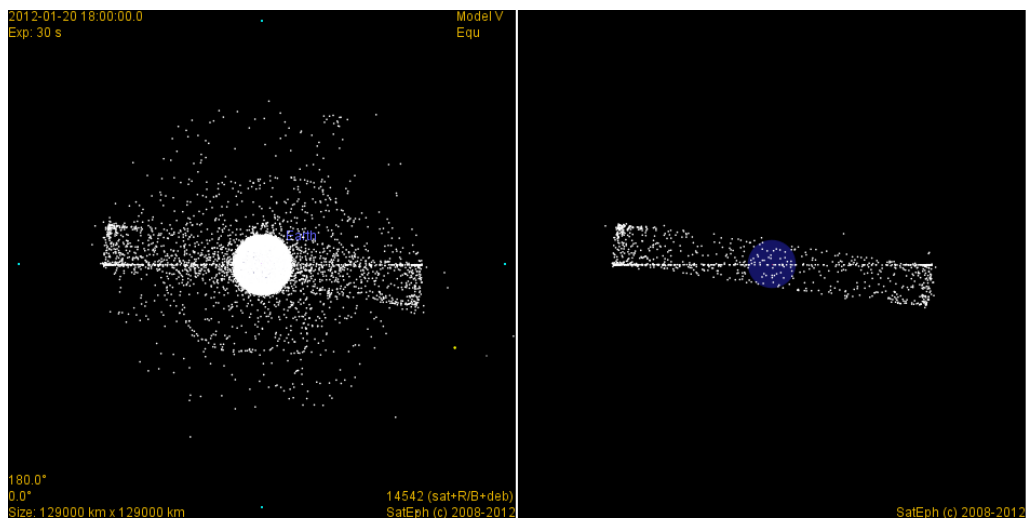
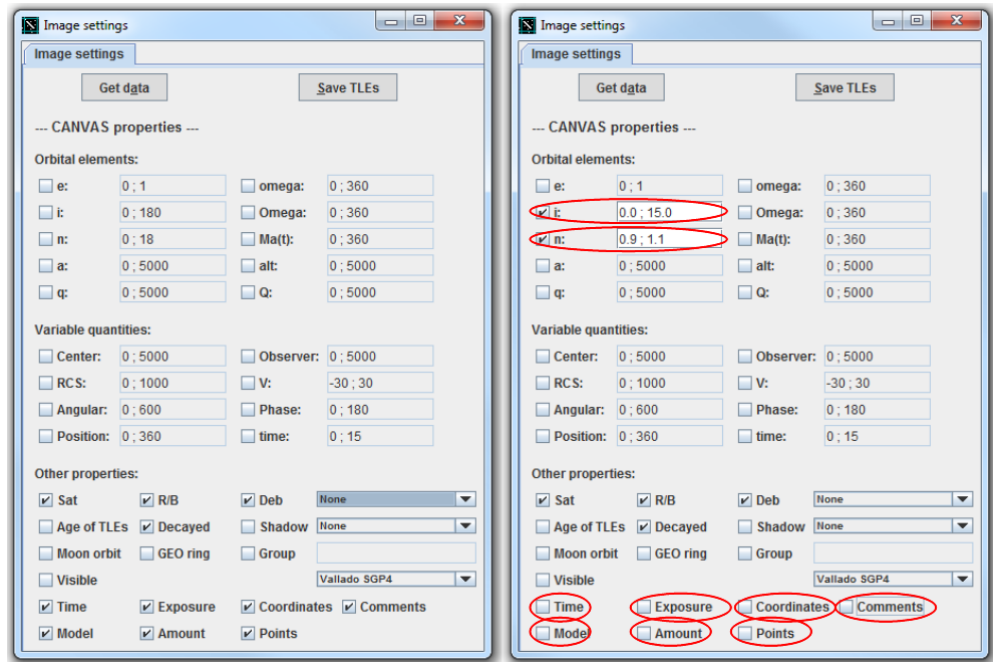


Figure 8.17 - Image settings windows (upper figures) and canvases (lower figures). On the left is plotted settings window (up) with no conditions set and canvas (down) with all objects plotted. On the right is plotted settings window (up) with selected criteria for inclination and mean motion (red cicled on the upper part of the figure) and with unchecked boxes for plotting properties (red cicled on the lower part of the figure). In this case on canvas on the right only objects passing selected conditions are plotted.



User can use text-fields and check-boxes situated on Image setting window to set conditions for plotting as is demonstrated in Figure 8.17 (figures on the right). Only objects situated on GEO type of orbit with inclination between  $0^{\circ}$  to  $15^{\circ}$  and mean motion between 0.9 to 1.1 revolutions per day are plotted (Figure 8.17, lower right corner). Also additional information such as time or coordinates is also not plotted after the checkboxes were unchecked. In following table all functions used in Image settings window are listed.

Variable	Comments
<b>Orbital elements:</b>	The boundary values will be compared to the TLEs of plotted objects
<i>e, omega, i, Omega, e, n, Ma(t), a, alt, q, Q</i>	The semi-major axis a, altitude alt, perigee q and apogee Q values should be set in 1000s of kilometers
<b>Variable quantities</b>	The boundary values will be compared to the calculated variables
<i>Center, Observer, RCS, V,</i>	The distance Earth's center-satellite and observer-satellite in 1000s of kilometers
<i>Angular, Phase, Position, time</i>	Angular stands for angular velocity calculated from equatorial coordinates, Phase stands for position angle calculated from equatorial coordinates
<b>Other properties</b>	These checkboxes are used for additional plotting conditions
<i>Sat, R/B, Deb</i>	By using these checkboxes user can choose what kind of objects should be plotted.
<b>Age of TLEs</b>	Selecting this checkbox objects color will appear according to the age of their TLEs
<i>Decayed</i>	All objects which are marked as decayed in 'ssr.txt' file will be plotted if they have available TLEs
<b>Shadow</b>	Objects in the Earth's eclipse won't be plotted on canvas, in case of 3D plots the objects will be shadowed
<i>Moon orbit, GEO ring</i>	This is valid only for 3D plot on canvas. The Moon orbit and GEO ring will appear on canvas
<b>Visible</b>	Should be plotted only objects which are visible from user geodetic position.
<i>Time, Exposure, Coordinates, Comments, Model, Amount, Points</i>	Additional data plotted on the canvas

Combo-boxes options – These menu items are marked by red circles in Figure 8.18. By menu on the left user is able to choose what kind of information should be plotted next to the objects position on canvas (its eccentricity, inclination, RCS, angular velocity etc). In the middle is plotted menu for choosing the Earth's plots. The options 'Ellipsoid' and 'Ellipsoid + continents' will plot the Earth as a transparent ellipsoid and non-transparent ellipsoid respectively. In case that option 'Ellipsoid + HD map' is chosen program will read images called 'earth.jpg' and 'earth\_lights.jpg' situated in program's subdirectory 'Sateph 2\pictures'. These images, which should be 2D Earth's maps will be used as a plots for the Earth in 3D plot.

On the right image is plotted the option for choosing model for ephemerides calculation. First model called 'Vallado SGP4' is the best verified model, the model 'Funk SGP4/SDP4' is model based on translation of SGP4 and SGP4 models from former FORTRAN code and its ephemerides are in great agreement with the 'Vallado SGP4' model. User can also choose option Kepler where program will calculate ephemerides assuming Keplerian motion.

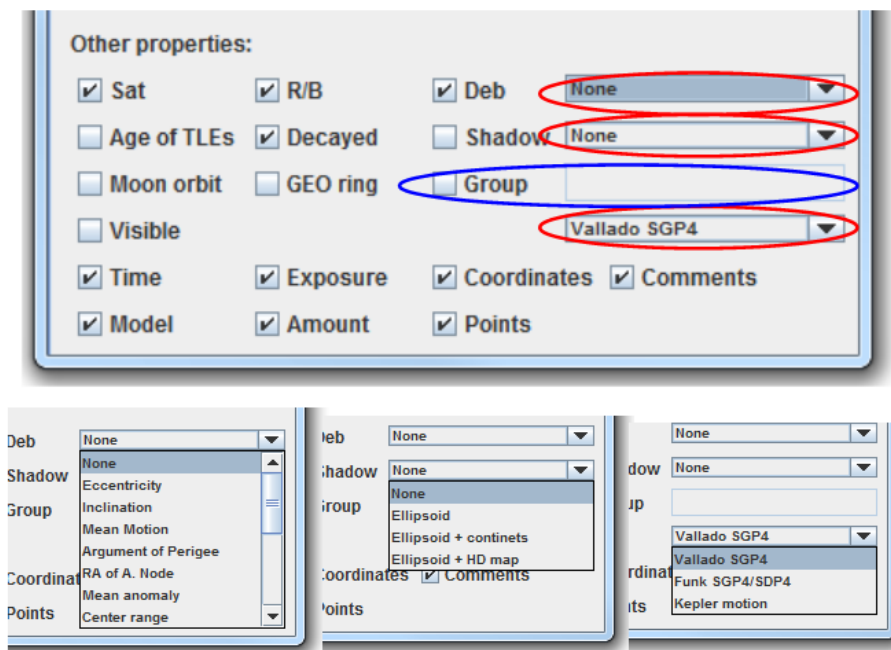


Figure 8.18 - Comboboxes (red circled) and checkbox 'Group' with text-field (blue circled). One can choose what kind of information should be plotted with object on the canvas (lower figure on the left), how the Earth should be plotted on 3D plot (lower figure in the middle) and what kind of model should be used for ephemerides calculation (lower figure on the right).

**Checkbox 'Group' and text-field** – In Figure 8.18 the checkbox 'Group' with text-field are marked by blue circle. These two components can be used to select what objects should be plotted on the canvas according to their international designator or name. In Figure 8.19 an example of input formats is plotted. Using string set in the left image only object which names contain string 'fengyun 1c' will be plotted on canvas. Using string set in the middle image only object with specific NORAD number will be plotted, in this case satellite Fengyun 1C (NORAD 25730). Using string set in the right image only object which international designators contain string '1999-025' will be plotted on canvas.

Figure 8.19 - Examples of inputs for checkbox 'Group' with text-field. Using text set on the right only objects which name contains string 'fengyun 1c' will be plotted. Using text in the middle only object with NORAD number 25730 will be plotted. Using text on the right only objects which international designator contains string '1999-025' will be plotted.

## 8.4 Identification window

This window consists from four sections, namely 'Two positions', 'Orbit determination', 'D criterion' and 'TLE converter'. All 'Identification' window sections are further discussed in following sections.

### 8.4.1 Two positions section

Using this section one can directly compare two ephemerides positions with the calculated ones to find the right match. In Figure 8.20 is an example of use of the 'Two positions section'. By red circles the input data are marked. User can choose in which coordinates the data will be written by choosing between 'Equatorial coordinates' or 'Horizontal coordinates'. Two positions for two measurement times are set. In text-fields starting with 'T:' the times are set in following form 'YYYY MM DD HH MM SS.SS' or 'YY MM DD.DD' where YYYY is for year, MM for month, DD for day, HH for hour, MM for minutes and SS.SS seconds or as is plotted in Figure 8.20. In the middle upper text-field the right ascension or azimuth values are set, where right ascension is in hours and azimuth in degrees. Valid are forms for right ascension 'HH MM SS.S' or 'HH.H' where H are hours, M minutes and S seconds and for azimuth 'DD AM AS.AS' or 'DD.D' where DD are degrees, AM are arc-minutes and AS.AS are arc-seconds. For declination and elevation same formats are valid as for azimuth. User can also set value for apparent magnitude of object marked as 'm:' on this section.

User can set comparison conditions by filling the text-fields (marked by green circles in Figure 8.20) 'd\_A', 'd\_AS' and 'd\_PA'. Text-field 'd\_A' stands for the maximum tolerable angular difference between the 1st position set by user and positions calculated for all objects by Sateph for set measurement time which should be the same as '1<sup>st</sup>

position' time. This value should be set in degrees. Text-field 'd\_AS' stands for maximum tolerable difference in angular velocity values between angular velocity calculated from set of positions and velocities calculated for all objects by Sateph. This value should be set in arc-minutes per minutes. Text-field 'd\_PA' stands for maximum tolerable difference in position angle values between position angle calculated from set of positions and position angles calculated for all objects by Sateph. This value should be set in degrees.

After the button 'Get objects' is pushed set values will be read and data compared with data calculated by Setph. User can see results of this procedure in text-fields marked by blue circle in Figure 8.20. In text-area plotted on the bottom of the figure (blue big circle) results from comparison will be listed with objects which passed the set conditions. In case plotted in Figure 8.20 the best fit was for object 16925.

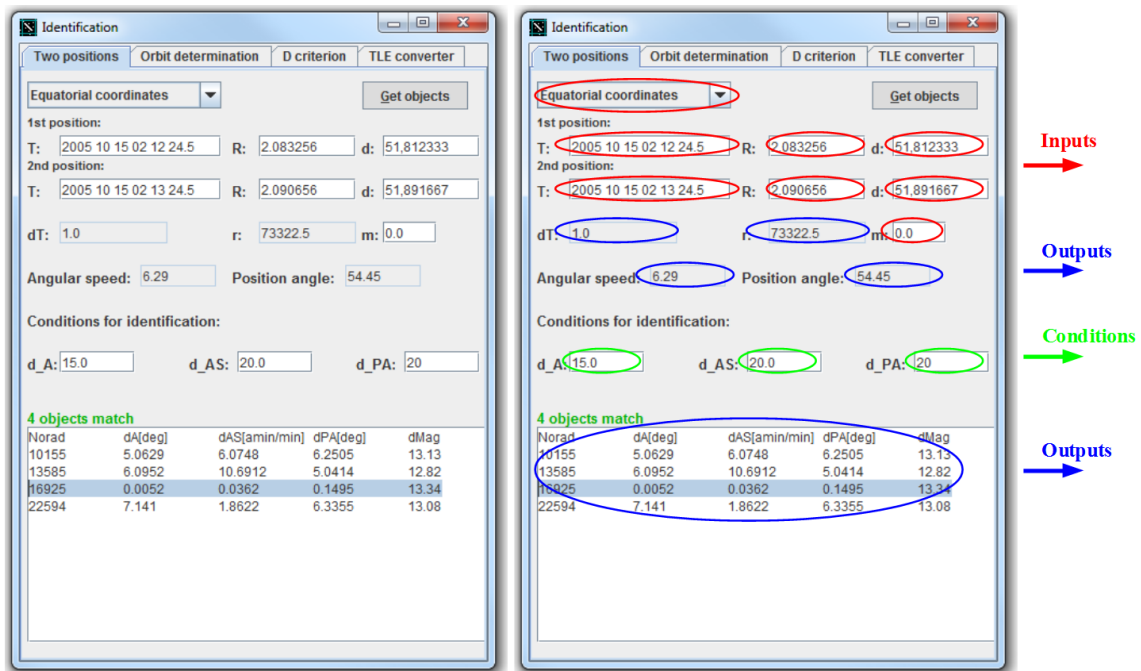


Figure 8.20 - Example of use of the 'Two positions' section.

## 8.4.2 Orbit determination section

This section is dedicated to preliminary orbit determination process using measured astrometric positions. Obtained orbital elements can give observer further information about unknown object accidentally tracked during observations, about its orbital inclination, distance, semi-major axis etc. In Figure 8.21 a demonstration of how to use this section is plotted.

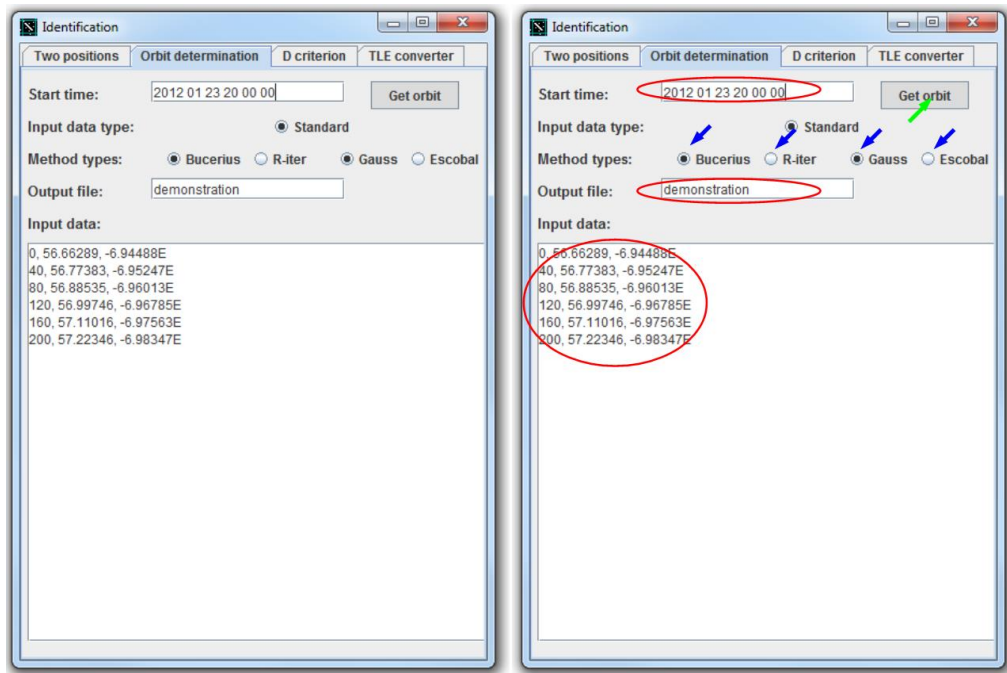


Figure 8.21 - Example of use of the 'Orbit determination' section.

User can set following parameters. User has to set observation starting time. In the example this time is set to value '2012 01 23 20 00 00' (Figure 8.21, red circle on the top). The ephemerides should be listed in the text-area (large red circle in the right image). Their format is explained in Figure 8.22. In first column is time in seconds since the set observation starting time, respectively how many seconds since set observation starting time passed till given ephemerides time. E.g., the first ephemeris with RA = 56.66289 deg and deg = -6.94488 deg is fixed to observation time '2012 01 23 20 00 00'. The second ephemeris is fixed on time '2012 01 23 20 00 00' + 40 seconds thence '2012 01 23 20 00 40' etc. In second column are right ascension values in degrees! In the third column the declination is listed [deg]. All columns must be separated by commas as is demonstrated in the Figure 8.22. Every ephemerides line to be valid must have ending with letter 'E'.

Time since [s]	RA [deg]	Dec [deg]	Comma	Letter 'E'
0, 56.66289, -6.94488E	0, 56.66289, -6.94488E	0, 56.66289, -6.94488E	0, 56.66289, -6.94488E	0, 56.66289, -6.94488E
40, 56.77383, -6.95247E	40, 56.77383, -6.95247E	40, 56.77383, -6.95247E	40, 56.77383, -6.95247E	40, 56.77383, -6.95247E
80, 56.88535, -6.96013E	80, 56.88535, -6.96013E	80, 56.88535, -6.96013E	80, 56.88535, -6.96013E	80, 56.88535, -6.96013E
120, 56.99746, -6.96785E	120, 56.99746, -6.96785E	120, 56.99746, -6.96785E	120, 56.99746, -6.96785E	120, 56.99746, -6.96785E
160, 57.11016, -6.97563E	160, 57.11016, -6.97563E	160, 57.11016, -6.97563E	160, 57.11016, -6.97563E	160, 57.11016, -6.97563E
200, 57.22346, -6.98347E	200, 57.22346, -6.98347E	200, 57.22346, -6.98347E	200, 57.22346, -6.98347E	200, 57.22346, -6.98347E

Figure 8.22 - Orbit dtermination input data description.



listed as the semi-major axis [km] (column no.2), the eccentricity (column no. 3), the inclination [deg] (column no. 4), the argument of perigee [deg] (column no. 5), the argument of right ascending node [deg] (column no. 6), mean anomaly (column no. 7) and perigee (column no. 10). In column no. 11 the epoch for given elements in modified Julian date [day] is listed. In columns no. 8 and 9 the information about used method are listed, where 0 in column 8 means option ‘Bucerus’ and 1 means ‘R-iter’ and 0 in column 9 means option ‘Gauss’ and 1 means ‘Escobal’.

In Figure 8.24 is example of content of file ‘resultsGood.txt’. Data are listed as in file ‘results.txt’. Into this file is the program Sateph is saving only data which passed the condition for perigee higher than the Earth’s radius 6378.15 km.

0 - 1 - 4	67161.96321	0.214748364	4.353481487	119.8436240	60.43486156	336.5617029	1	0	14528.68629	55949.8333333333
0 - 1 - 5	69933.31363	0.214748364	4.316292742	118.3447873	60.93255170	337.8684698	1	0	14795.67179	55949.8333333333
0 - 2 - 4	73924.56166	0.214748364	4.273087036	116.4225966	61.56774921	339.5647281	1	0	15133.65098	55949.8333333333
0 - 2 - 5	75949.12107	0.214748364	4.250092307	115.4971421	61.88017624	340.3396282	1	0	15300.15289	55949.8333333333
0 - 3 - 4	76377.99822	0.214748364	4.229570706	115.1938825	62.00400713	340.4722715	1	0	15367.31094	55949.8333333333
0 - 3 - 5	78357.34049	0.214748364	4.216924506	114.4038115	62.26108898	341.1897186	1	0	15502.92929	55949.8333333333
0 - 4 - 5	80474.01242	0.214748364	4.204370740	113.6063554	62.52090567	341.9110143	1	0	15639.65556	55949.8333333333
1 - 2 - 4	82671.94770	0.214748364	4.187538907	112.7947427	62.79239156	342.6689222	1	0	15782.00178	55949.8337962963
1 - 2 - 5	83385.68097	0.214748364	4.179412626	112.5148904	62.89090308	342.8803272	1	0	15834.04453	55949.8337962963
1 - 3 - 5	83598.98570	0.214748364	4.164741910	112.3356356	62.97081159	342.9252026	1	0	15876.84456	55949.8337962963

Figure 8.24 - Example of content of 'resultsGood.txt' file generated by section 'Orbit determination'.

In the last generated file ‘resultsTLE.txt’ the orbital elements are listed in TLE form and can be used directly in program Sateph. These are the same elements as listed in ‘resultsGood.txt’. To plot this elements the model ‘Funk SGP4/SDP4’ is recommended to use which is available in window ‘Image settings’.

### 8.4.3 D criterion section

Once the user has available the TLE data of unknown object, he can use the section ‘D criterion’ to compare given elements with all other available orbital elements loaded into the program Sateph. In Figure 8.25 an example of usage of section ‘D criterion’ is plotted. The TLE data obtained by Sateph’s section ‘Orbit determination’ are compared with all available TLEs. Investigated was orbit determined for the meteor observed at AGO in April 2009. To compare the TLEs, user has to choose between two types of D criterions, ‘Soutworth - Hawkins’ and ‘Steel’ (upper right circle on the figure). User can also choose selection criterion values by setting the text-field ‘D:’, in Figure 8.25 set to value 0.02. In text-fields ‘1st line:’ and ‘2nd line’ user should input first and second TLE lines respectively (two large red circles in the middle of the figure). By using button ‘Get objects’ user will get the list of object which passed given criterion. In text-area (marked by blue circle) all objects which passed given criterion are plotted, in case of this example



only tanks from rocket bodies BREEZE-M are listed which means that those objects had the orbits most similar to the set TLE data for object 70000.

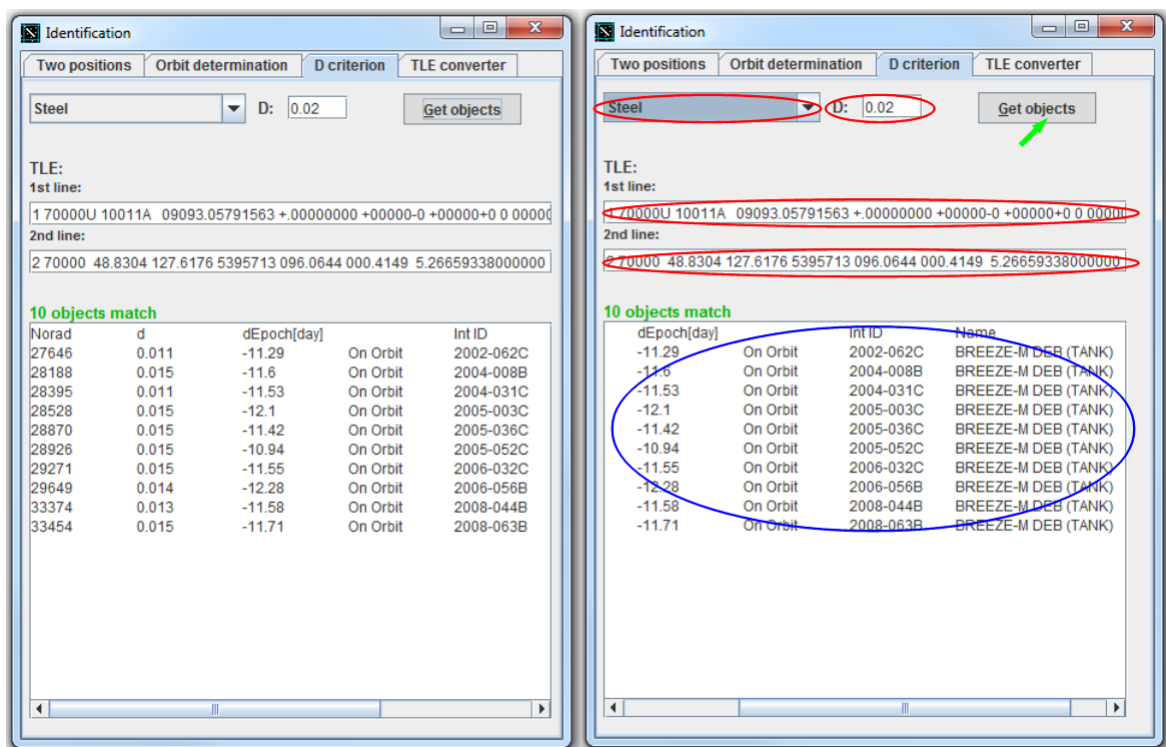


Figure 8.25 - Example of use of the 'D criterion' section.

#### 8.4.4 TLE converter section

This section is dedicated to the conversions between classical TLE formats and separated orbital elements values. An example of 'TLE converter' section usage is plotted in Figure 8.26. User has to choose which direction the data should be convert (upper red circle in the right image), from TLE format to separated values by choosing option 'From TLE to elements' and from elements to TLE format by choosing option 'From elements to TLE'. When the option 'From elements to TLE' is selected the program will read value for ephemerides time set in the left text-field 'Epoch' in MJD [day] (in the example '54936.53271834') not from the right text-field 'Epoch' (in the example set to '2009-04-15 12:47:06.86'). The conversion will occur when the button 'Convert' is pushed.

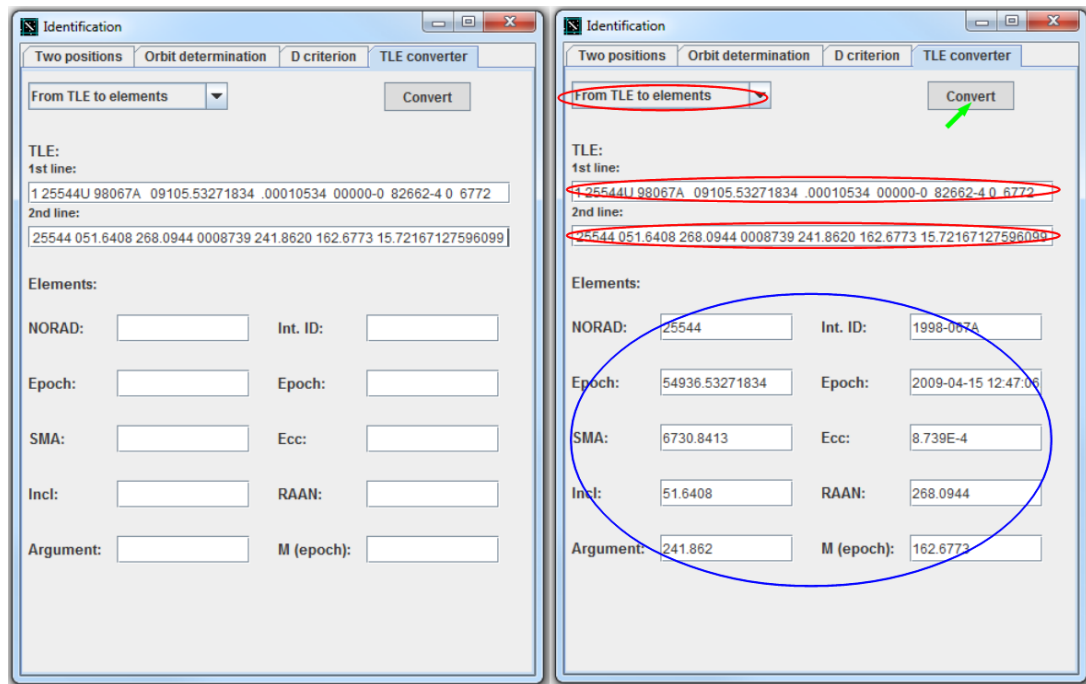


Figure 8.26 - Example of use of the 'TLE converter' section.

## 8.5 HD display window

This window can be activated by choosing menu item **'Tools / Show HD Display'**. In Figure 8.27 the HD display window is plotted with menu its item. User can choose what kind of coordinates should be used for plots. The geodetic coordinates 'Geodetic HD', topocentric horizontal coordinates 'Horizontal HD', topocentric equatorial coordinates 'Equatorial topoc. HD' and geocentric equatorial coordinates 'Equatorial geoc. HD' can be set. On HD display canvas also actual position of the Sun, Moon and the Earth's shadow in geostationary distance are plotted. By choosing option 'Geodetic HD' the image called 'earth2dmap.jpg' situated in subdirectory 'SatEph 2\pictures' will be plotted as background. By choosing menu item in main window **'File / Save picture'** generated image will be saved in subdirectory 'SatEph 2\save'.

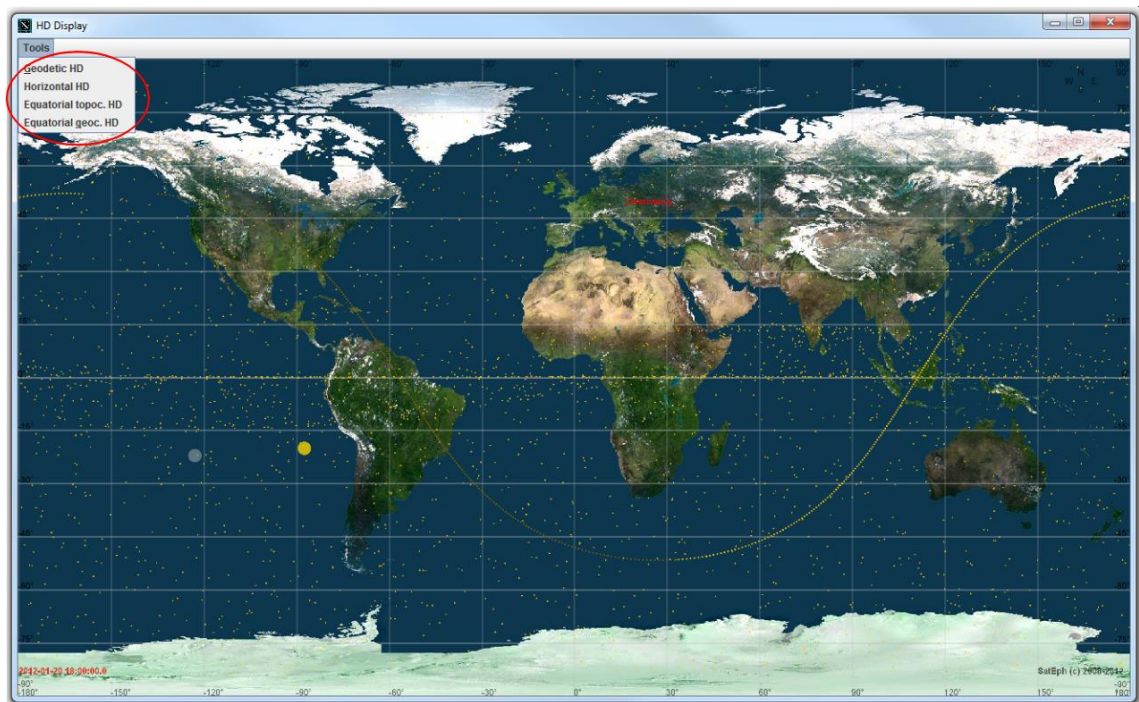


Figure 8.27 – HD display window with menu item. This item can be used for choosing the plotted coordinates. In figure the geodetic coordinates with ISS orbit are plotted.

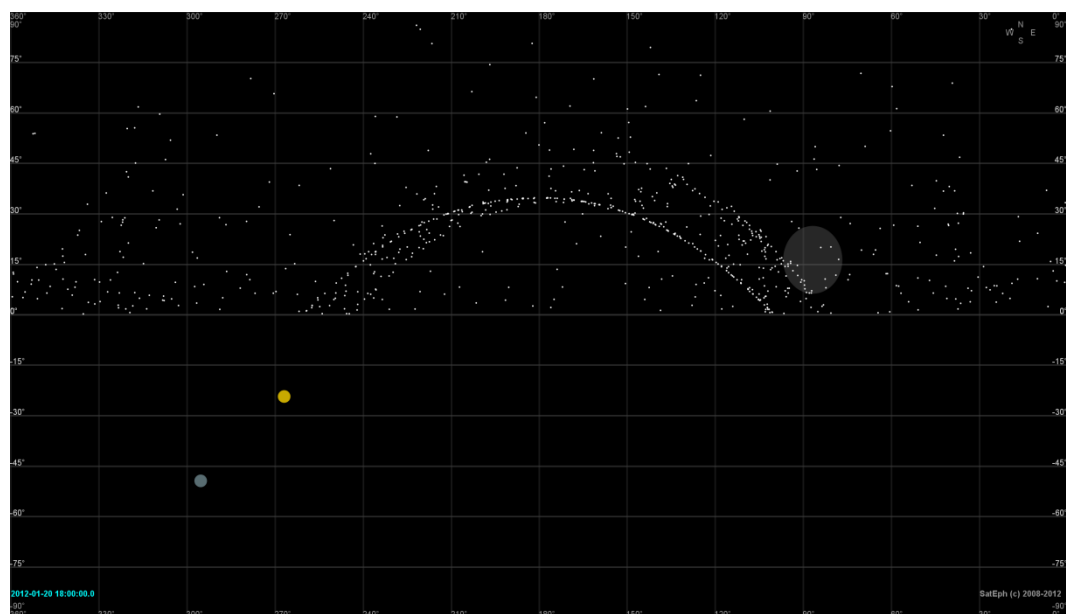


Figure 8.28 – Image generated by HD display window. In the figure the topocentric horizontal coordinates are plotted.

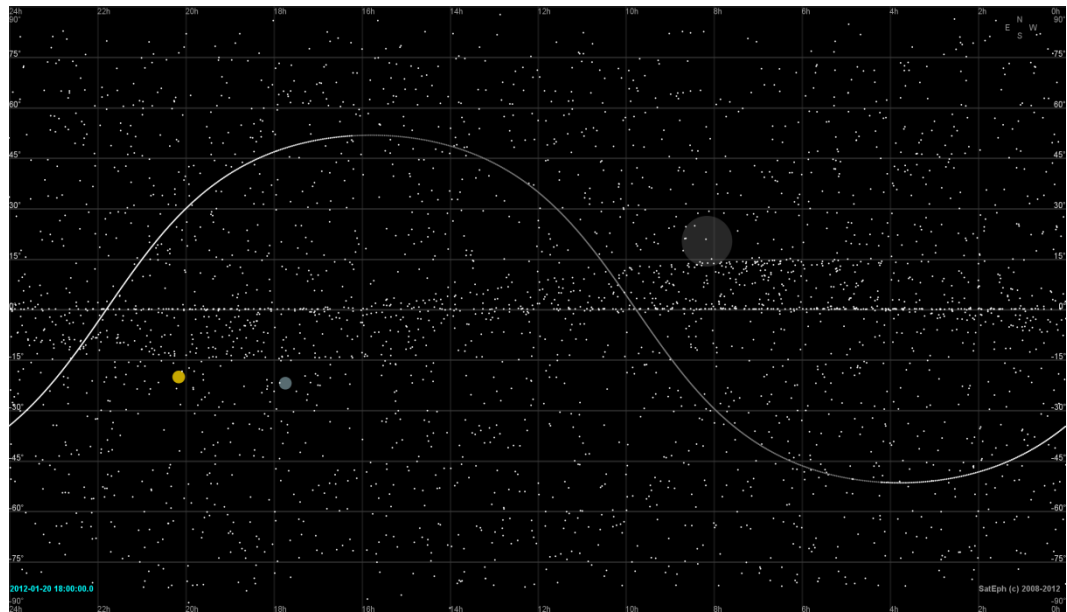


Figure 8.29 – Image generated by HD display window. In the figure the geocentric equatorial coordinates with ISS orbit are plotted.