TLE ANALYSER

User Manual v2.8

TLE analysis
Satellite tracking and orbit prediction
Exportation to GMAT, Celestia and Google Earth

12/12/2013

TLE ANALYSER

Version 2.8 - 2013

Summary

1. What is TLE Analyser?

Every object in orbit around earth is referenced and checked by the American NORAD. This organisation provides orbital parameters of unclassified satellites in a specific format called TLE (Two Line Elements).

***TLE Analyser* first mission** is to decode satellites TLE in order to extract the **osculating orbit** parameters and all other resulted data (velocities, altitudes, periods, precession movements…)

The second mission of *TLE Analyser* is to make prediction on satellite position. 2 *graphic* tracking modes are available (2D and 3D).

Third mission of *TLE Analyser* is to export TLE parameters to different 3D spatial applications (NASA GMAT, Celestia and Google Earth).

TLE Analyser can also manage ground stations or places for satellite time passing.

- ***TLE Analyser* provides data with reference to Simplified General Perturbations models (SGP4/SDP4), see §12.**
  These models predict the effect of perturbations caused by the Earth's shape (spherical harmonics), drag, radiation, and gravitation effects from the Sun and Moon.
  The SGP4 model has an error ~1 km at epoch and grows at ~1–3 km per day.
  TLE Analyser can predict satellite position many years before and after TLE epoch but you should keep a range of +/- 10 days to have good prediction.

- **Internet connection must be effective for TLE updater and Google Earth visualization.**

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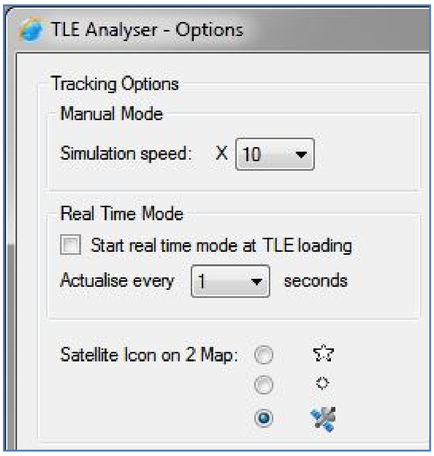
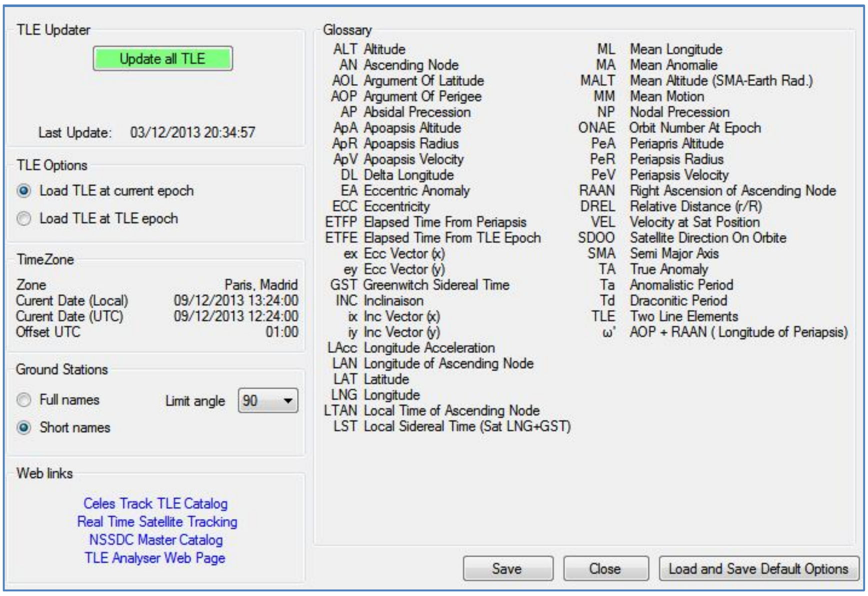
2. TLE Analyser Setup and Options



- **TLE Updater** allow to download last versions of all TLE used by TLE Analyser
  - TLE files are located in C:\TLEAnalyser\TLE\

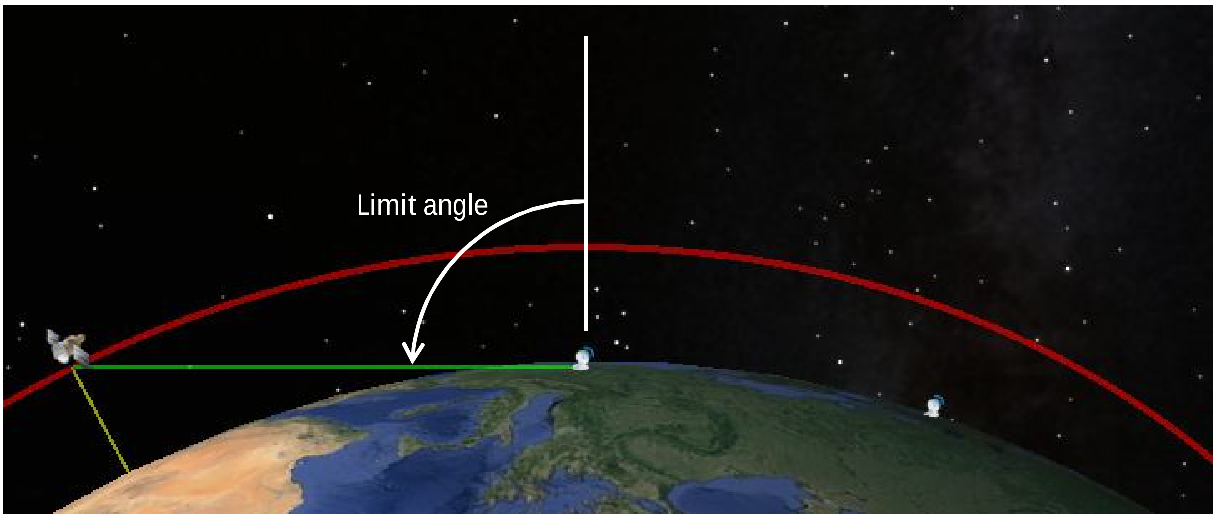
- **Tracking options** allow to choose:
  - **Real Time Mode:**
    - **Start Simulation at TLE Loading:** Real Time Mode automatically starts when you import a TLE
    - You can chose the frequency of the datas display (**Actualise)**
  - **Manual Mode:**
    - **Speed** : frequency of actuation:
      - x1= 1 step/s (1 sec. between each step)
      - x10= 10 steps/s (0,1 sec. between each step)
      - x100= 100 steps/s (0,01 sec. between each step)
  - **Satellite icon** on standard 2D map

- **Export to GMAT.script (R2013a)**:
  - **Show Track Plot**: GMAT can display a 2D map of satellite propagation
  - **Partial or Full model**: choose among 2 options of force models
  - **Propagate:** propagate duration (based on Draconitic Period)



- **Web Links option** provides some links to useful websites:
  - CelesTrack TLE Catalog: Catalog of TLE used by TLE Analyser
  - Real Time Satellite Tracking: Satellite Tracking on the web (Google Map)
  - NSSDC Master Catalog: Here you can find some details of loaded satellite
  - TLE ANALYSER WEB SITE: Web Page of TLEA on Sourceforge.net

- **Ground Stations option:**
  - The Limit Angle is the range of visibility



- The **Glossary** provides a definition of each acronyms used in TLE Analyser

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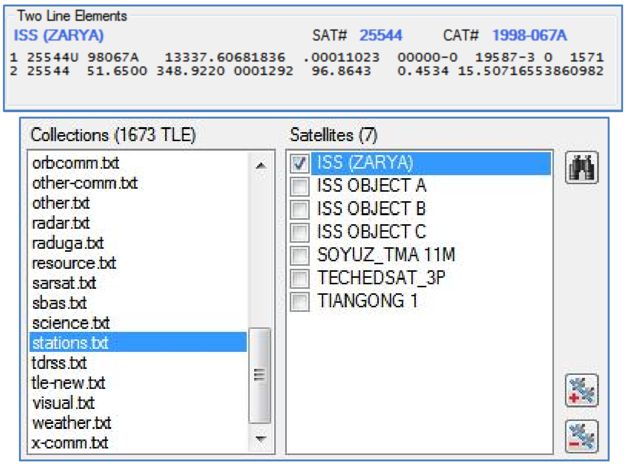
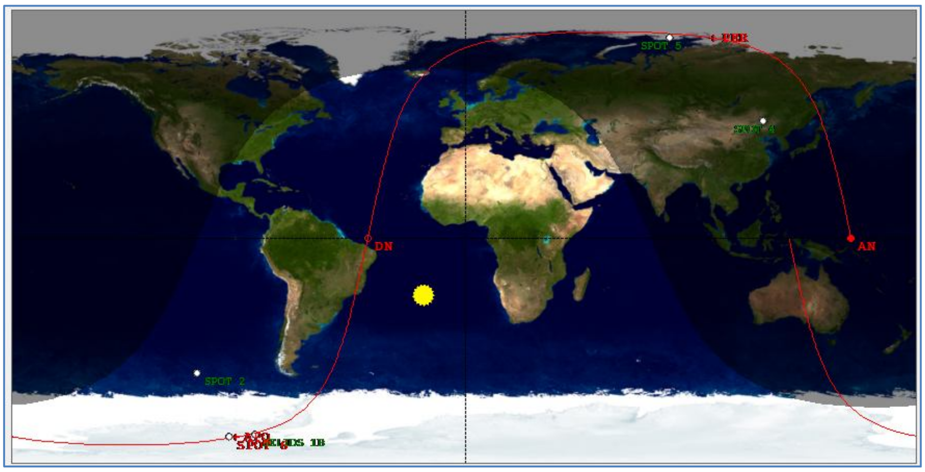
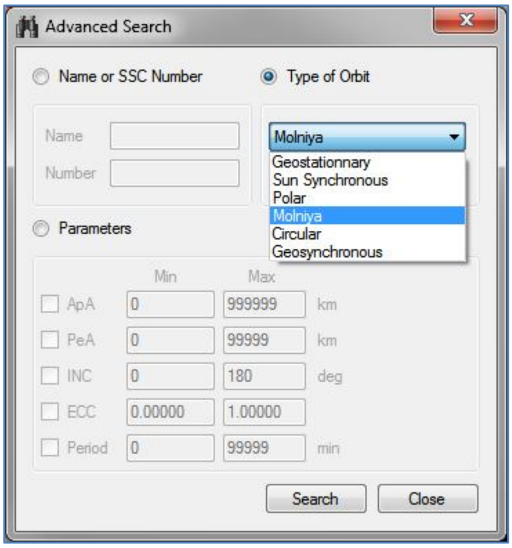
3. Import/Modify a TLE



- Import a TLE:
  - Choose an available satellite in collections.
  - Satellite is automatically imported at **Current UTC date** or at **TLE Epoch** (to choose in **Options**)
  - Click on  button to use the complete search engine
  - Click on  button allows you to paste your own **2 lines**
  - Click on  buuton to accept the new TLE.
  - When a TLE is imported, click on  to change Keplerian values in the **2nd line**.
    - Be careful to respect characters positions (use **Show Details** to be sure)
    - Click on **IMPORT** button to accept the new TLE.
  - You can display several satellites on the 2D map
    - Select a satellite to display position and track (1st click)
    - Check a satellite to keep its position on the map (2nd click)
    - Double-Click on a satellite on a map to display its track



4. Search Engine



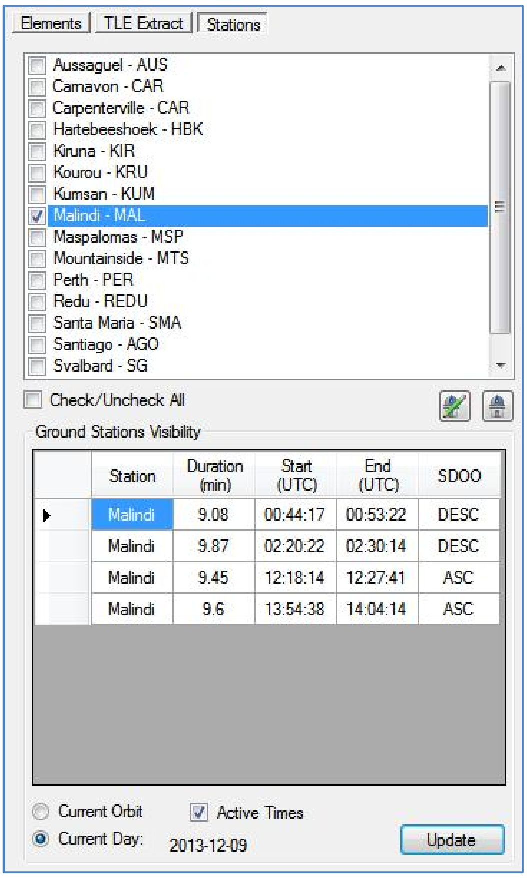
This complete Search Engine allows you to find any satellite in 4 specific search modes:

- By Name or Satellite Number
- By type of orbit
- Or by choosing from 1 to 6 orbital parameters

Specificities for “Type of Orbit” option:

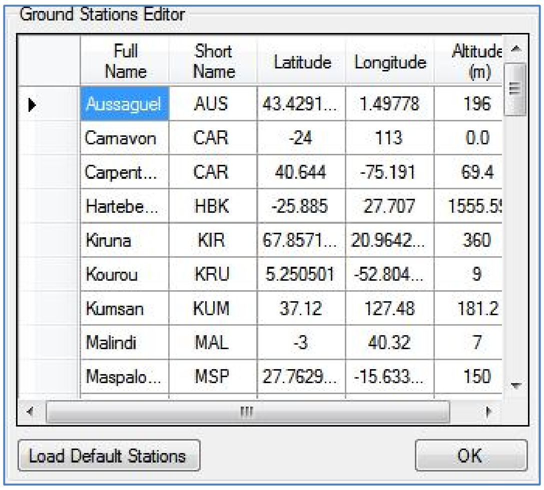
- **Geostationnary**:
    - 0.99 < MM < 1.01
    - 0.01 < INC < 0.1
    - ECC < 0.01
- **Sun Synchronous**:
    - 0.97 < NP < 1
- **Polar**:
    - 89 < INC < 91
- **Molniya**:
    - 60 < INC < 65
    - ECC > 0.5
- **Circular**:
    - ECC < 0.01
- **Geosynchronous**:
    - 0.99 < MM < 1.01

5. Ground Station management



- **Ground Stations (or other places you want)** management is available:
  - Directly from the list in “C:\TLEAnalyser\GroundStations.txt” file (TLE Analyser must be closed and re-opened to take effect), each line contains one station parameters:
    - Full name
    - Short name
    - Station latitude
    - Station longitude
    - Station altitude

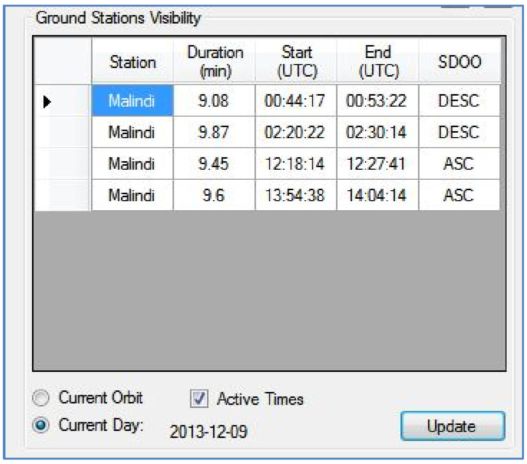
- Or using this button  :



Full Name	Short Name	Latitude	Longitude	Altitude (m)
Aussaguel	AUS	43.4291...	1.49778	196
Carnavon	CAR	-24	113	0.0
Carpent...	CAR	40.644	-75.191	69.4
Hartebe...	HBK	-25.885	27.707	1555.5!
Kiruna	KIR	67.8571...	20.9642...	360
Kourou	KRU	5.250501	-52.804...	9
Kumsan	KUM	37.12	127.48	181.2
Malindi	MAL	-3	40.32	7
Maspalo...	MSP	27.7629...	-15.633...	150

In this case, stations can be added, deleted and modified without clothing the TLEA. **Default** button load initial stations.

- **The second button**  open a data grid with time passing above selected stations:

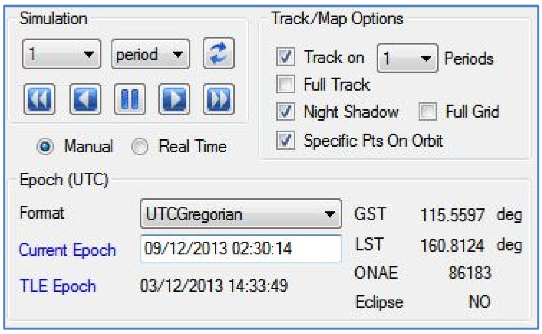


Station	Duration (min)	Start (UTC)	End (UTC)	SDOO
Malindi	9.08	00:44:17	00:53:22	DESC
Malindi	9.87	02:20:22	02:30:14	DESC
Malindi	9.45	12:18:14	12:27:41	ASC
Malindi	9.6	13:54:38	14:04:14	ASC

- **Active Times** means that user can click on time cells to position the satellite on the map.

6. Tracking and Maps

- When a TLE is imported, the tracking tools are enabled and satellite position can be estimated with following options:



- o **Epoch** parameters:
  - ▪ **Gregorian** and **Modified Julian Date** are available
  - ▪ Click on **Current Epoch** to use *Current UTC* Date
  - ▪ Click on **TLE Epoch** to use *TLE UTC* Date
- o **Simulation Mode:**
  - ▪ Allow to choose **Manual** or **Real Time** mode
- o **Track Options:**
  - ▪ Allow to generate from 1 to 15 periods track.
  - ▪ Allow to generate **Full Track**
    - ➢ The Full Track is not available in Google Earth view
    - ➢ The Full Track is a prediction at T0
  - ▪ Allow to display **Day/Night** on **Standard Map** and on **Google Earth**.
  - ▪ Allow to display **full grid** of meridians on standard Map.

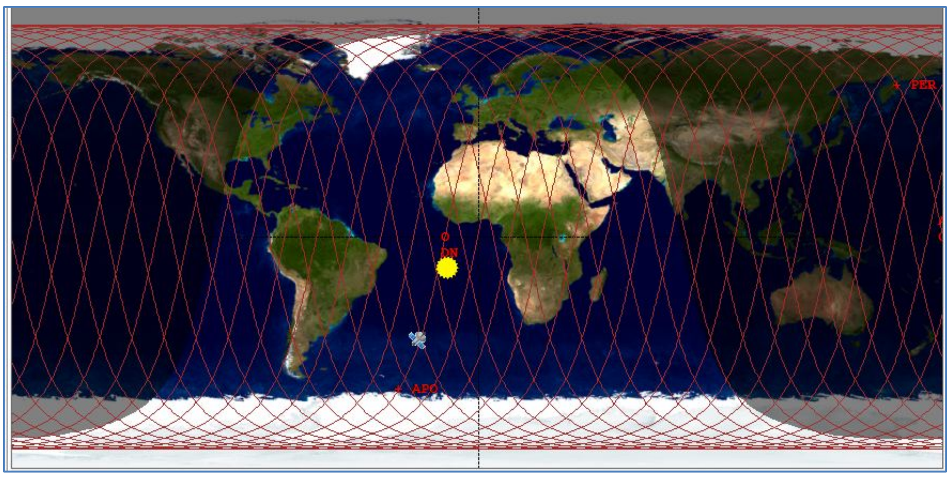
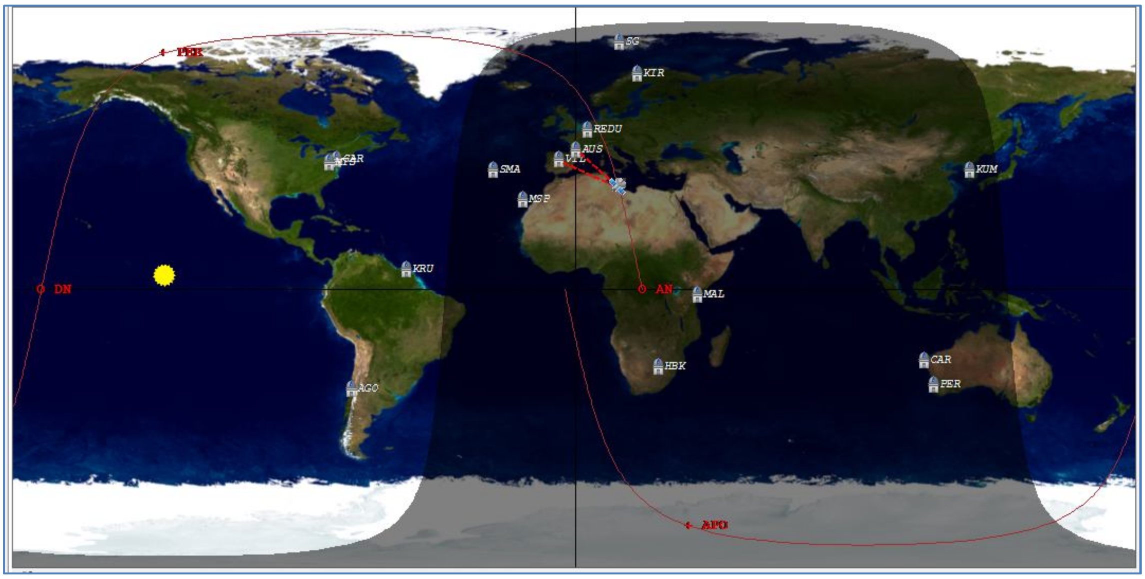


Figure 1: Example of full track display

• Standard Map (based on a Equirectangular projection)

- You can visualise the satellite **track** on different periods (from 1 to 15)
- Positions of the Satellite and position of the Sun are available.
- The track starts from the ascending node to the descending node of the orbit
- Apoapsis and Periapsis points are displayed



- More info about Phasing parameters:

Periods		
Tk	92.9271	min
Ta	92.8603	min
Td	92.799	min
Phasing	[15 ; 15 ; 29] 450	

- Phasing form is: **[n ; p ; q] r**
  - n = Entire part of the daily phasing frequency
  - p / q = Fractional part of the daily phasing frequency
- That mean:
  - The Satellite performs “r” revolutions in “q” days.
  - n + (p/q) = Number of orbit per day
- These parameters are usually used for specific Low Orbit missions.
  - **As TLE provide osculating parameters, the Phasing provided by TLE Analyser is correct as long as the Satellite is frequently maintained on his mean orbit.**
  - **As some satellite don’t need to be phased, the phasing parameters are not useful.**
  - **In some cases, the phasing parameters can be wrong (e.g. ISS)**

- ## Google Earth

  - This view mode provides a 3D view from **Google Earth API**
  - **Google Earth plugin must be installed in your web browser.**

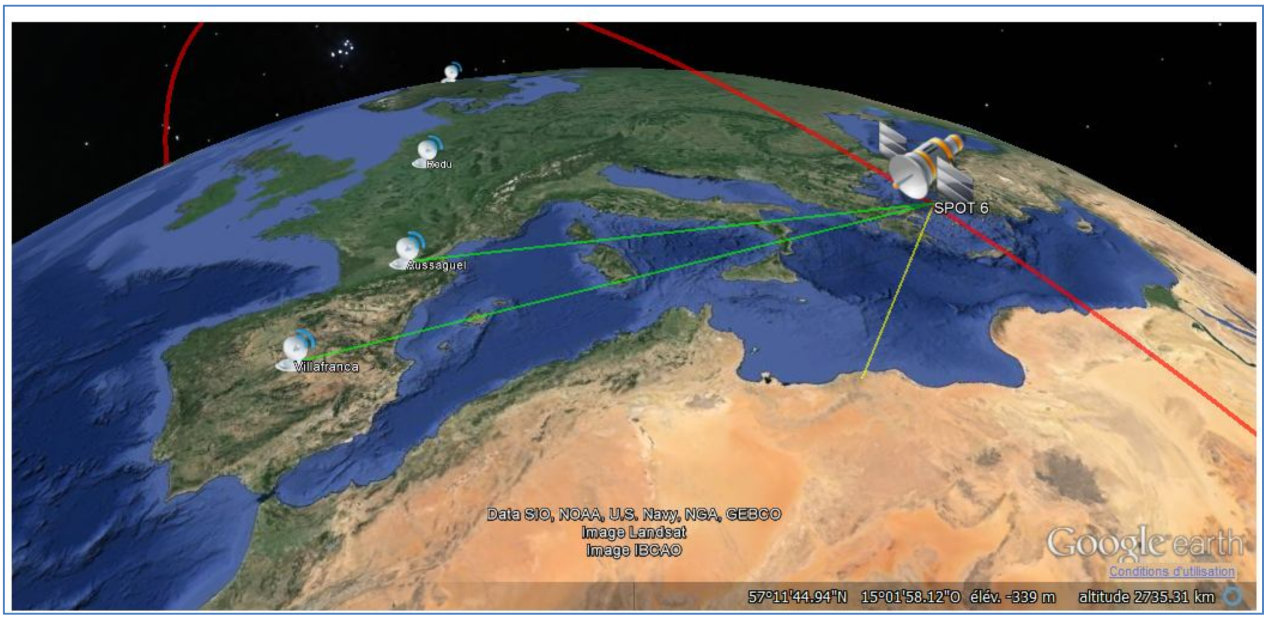


Figure 2: Large view on Spot6 near its passing over Europe

7. XY Plot Generator

TLE Analyser allows you to generate XY Plot for some orbit parameters.

- First of all, a satellite must be loaded
- 5 time options are available (minutes, hours, period, days, years)

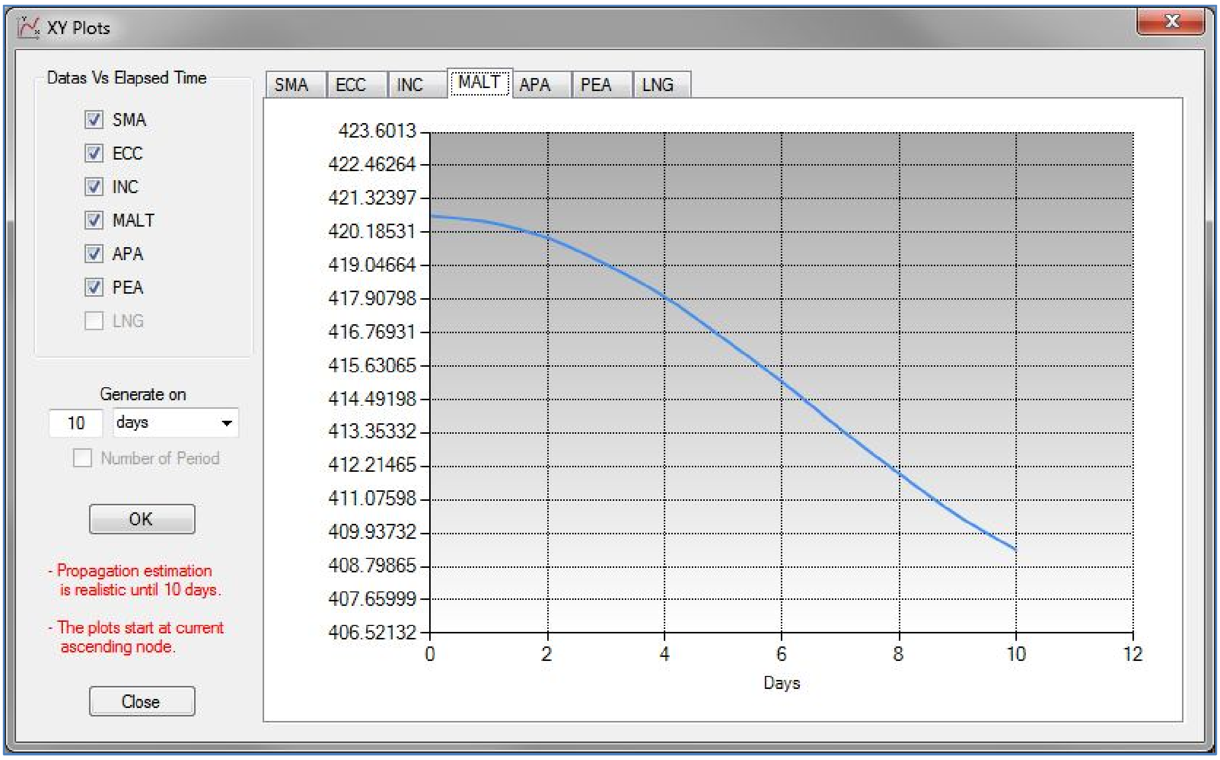
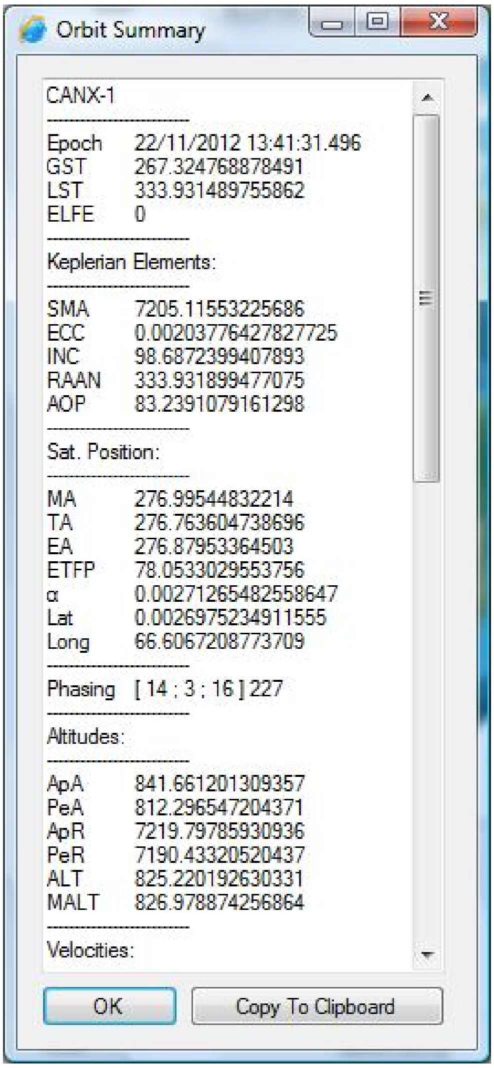


Figure 3: Example for ISS during 10 days

8. Menu

- ### TLE Menu
  - **Open Favorites**: Load *Favorites.txt* file into TLE list
  - **Save to Favorites**: Save current TLE into C:\TLEAnalyser\FAV*Favorites.txt*
  - **Delete from Favorites:** Delete current TLE from Favorites
  - **Report**: Display a complete report of all obit parameters.



- ## Export Menu
  - **Export To GMAT:**
    - Allow to generate a **GMAT** *.script* file to be directly used by the NASA software.
  - **Export a Formation to GMAT:**
    - Allow to generate a **GMAT** *.script* file with several satellites in the same file.
    - Use  buttons to **add** or **delete** satellites in the "formation" list.
    - The export is done at active Epoch!

<u>For both options:</u>

- GMAT *.script* files are located in C:\TLEAnalyser\GMAT\
- GMAT *.script* files are optimised for GMAT R2012a and R2013a version

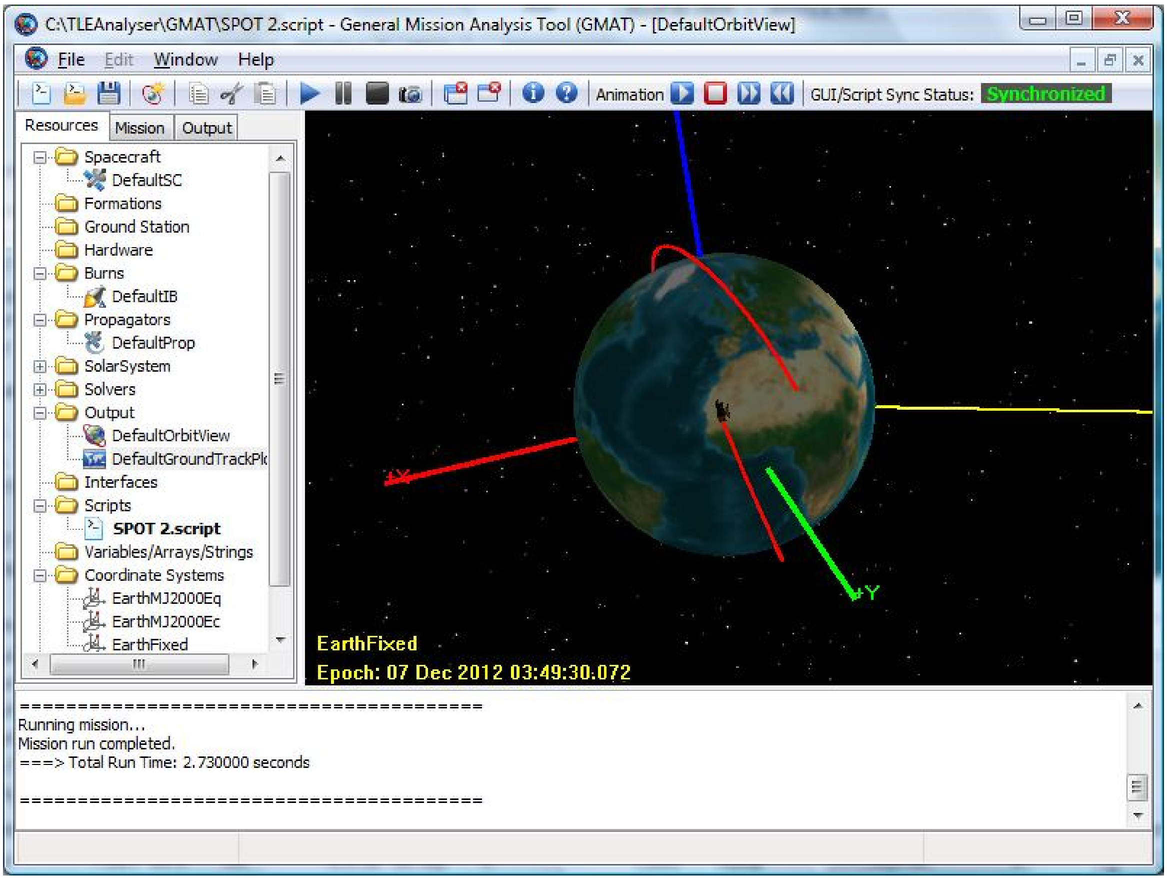


Figure 4: GMAT View

- **Export To CELESTIA:**

- Allow to generate a **Celestia** Folder to be directly used by the famous software.
- **Satellite** folder is located in C:\TLEAnalyser\CELESTIA\
- The folder can be directly paste into **Extras Celestia's** folder
- Don't forget to enable "Orbit" option in **Celestia**.
- **Be careful, it seems that Celestia doesn't use SGP model. It would be better to choose the effective epoch before export to Celestia.**

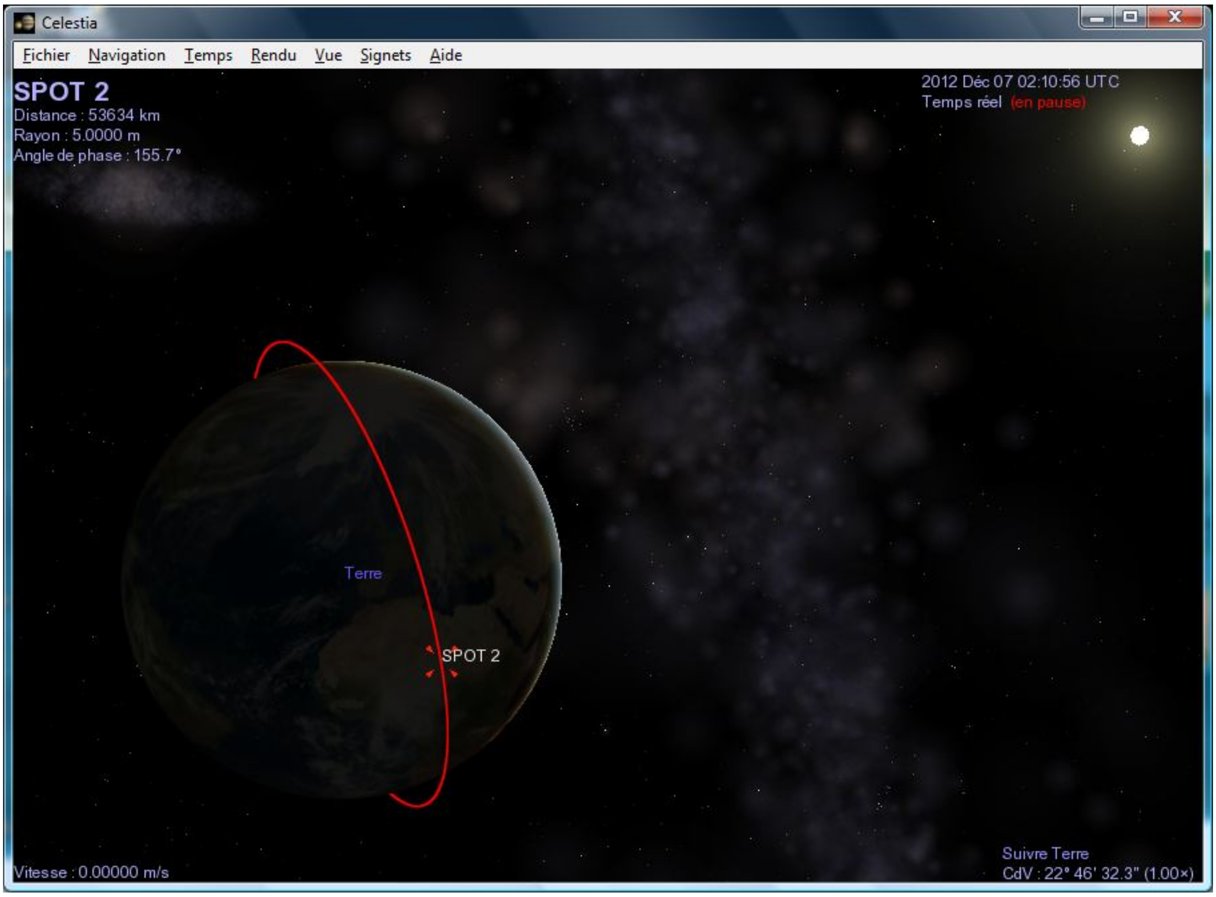


Figure 5: Celestia view

- **Export To Google Earth:**
  - Allow to generate a Google Earth Folder with .kml file and satellite.png file
  - Satellite folder is located in C:\TLEAnalyser\GOOGLEEARTH\
  - Satellite.kml file can be directly executed from this folder
  - Export is not enabled for **Full Track Mode**
  - **Exporting time might be longer for more than 1 periods tracks**

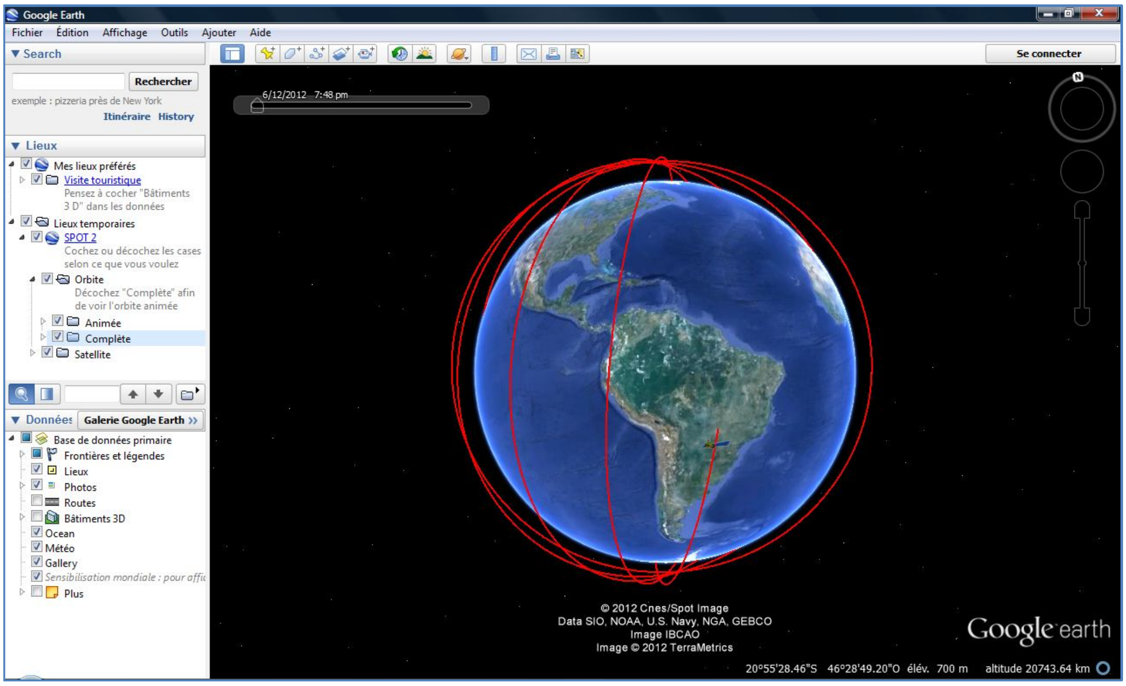


Figure 6: Google Earth View

- **Options Menu**
  - **XY Plots:** Allow to generate XY Plots
  - **TLE Analyser Options**: Display program's options (**see §2**)
  - **About TLE Analyser:** Display the README file with information about version and updates.
  - **Help:** Display the User Manual (pdf)
  - **Exit:** Allow to Exit TLE Analyser

9. Shortcuts

(Focus must be out of the Maps)

- Open Favorites: Ctrl + O
- Save to Favorites: Ctrl + S
- Export to GMAT: Ctrl + G
- Export to Google Earth: Ctrl + L
- Export to Celestia: Ctrl + T
- Summary: Ctrl + M
- About: F2
- Help: F1

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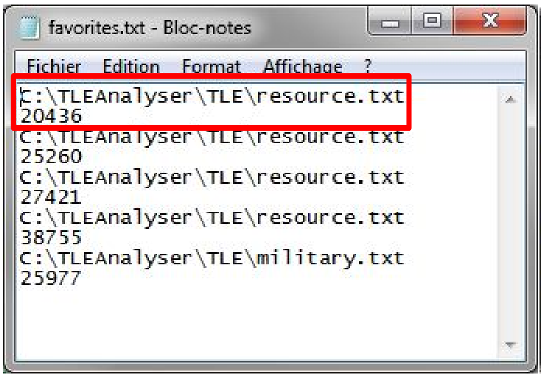
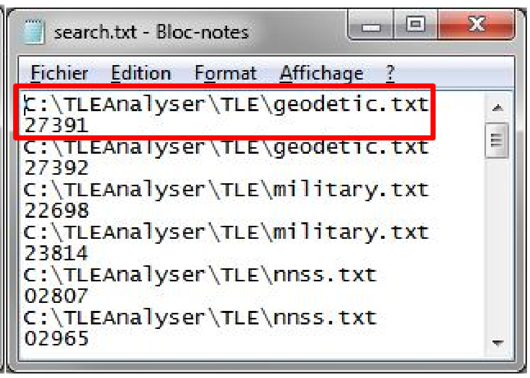
10. Error Handling

• Files format

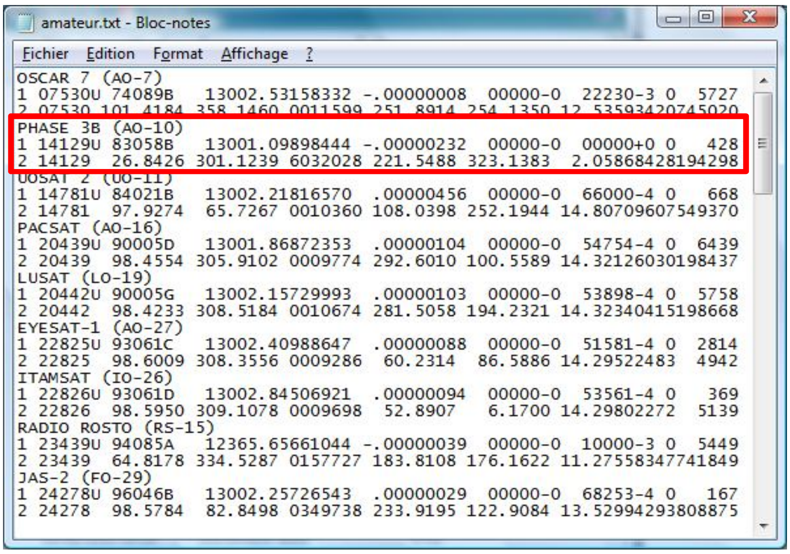
Corrupted files should provide errors during TLE ANALYSER using.

- **Favorites and Search files** (C:\TLEAnalyser\FAV\) must keep following format:
  - o 2 lines for 1 satellite:
    - ▪ 1st line for the **Collection file name**
    - ▪ 2nd line for the **satellite number**





- **TLE files** (C:\TLEAnalyser\TLE\) and **Formation file** (C:\TLEAnalyser\GMAT) must keep following format:
  - o 3 lines for 1 satellite:
    - ▪ 1st line for the satellite name
    - ▪ 2nd line is the Line 1 of the TLE
    - ▪ 3rd line is the Line 2 of the TLE



- **INI file** (C:\TLEAnalyser\tlea.ini) must keep the following format:

```
[TLE]
date=13/11/2013 08:41:28
version=2.6

[Tracking Options]
speed=10
SatVisual1=False
SatVisual2=True
SatVisual3=False
Simulation On=False
RealTimeStep=1
SatVisual4=

[GMAT Export]
show track=True
OptionGmatModel1=False
OptionGmatModel2=True
propagate=1

[TLE Options]
LoadTleNow=True
LoadTleEpoch=False

[Ground Stations]
GSFullName=False
GSShortName=True
LimitAngle=90
```

  - **Date** parameter corresponds to the last update of all TLE files.
    For a 1st installation and without TLE update with TLE ANALYSER, this date corresponds to the TLE provided by TLE ANALYSER.

- **Ground Stations file** (C:\TLEAnalyser\GroundStations.txt) must keep the following format:
  - 1 line for 1 station with between each ";":
    - Full Name
    - Short Name
    - Latitude
    - Longitude
    - Altitude

```
Carpenterville;CAR;40.644;-75.191;69.4
Hartebeeshoek;HBK;-25.885;27.707;1555.59
Kumsan;KUM;37.12;127.48;181.2
Mountainside;MTS;39.6;-77.76;187
Redu;REDU;50.003;5.145;332
Malindi;MAL;-3;40.32;7
Carnavon;CAR;-24;113;0.0
Santiago;AGO;-33.15139;-70.668402;705
Kourou;KRU;5.250501;-52.804627;9
Santa Maria;SMA;36.997047;-25.136003;200
Maspalomas;MSP;27.762914;-15.633806;150
Kiruna;KIR;67.857157;20.964274;360
Perth;PER;-31.804224;115.884705;44
Villafranca;VIL;40.442587;-3.951591;600
Svalbard;SG;78.229777;15.407778;430
Aussaguel;AUS;43.429175;1.49778;196
```

11. Mathematical Specifications

11.1. Time System

The time system used in TLE Analyser is the Coordinated Universal Time (UTC) provided in Gregorian format (GD) and Modified Julian Day format (MJD)

TLE Analyser extracts the **epoch year (YYYY)** and the **day of the year (DD.ddd)** from the TLE. Then, the TLE epoch is calculated (in MJD format):

$$\text{EPOCH}_{\text{TLE}} = \left(1721424.5 - int\left(\frac{YYYY-1}{100}\right) + int\left(\frac{YYYY-1}{400}\right) + int\big((365.25 * YYYY) - 1\big) + DD.ddd\right) - 2430000$$

11.2. Satellite State Representation

TLE Analyser uses the SGP4 method to extract Cartesian states from the TLE.

Symbol	Description
x	x-component of position
y	y-component of position
z	z-component of position
$\dot{x}$	x-component of velocity
$\dot{y}$	y-component of velocity
$\dot{z}$	z-component of velocity

Then, a conversion is done to obtain the osculating parameters. This method is the same used by GMAT described in the “GMAT Mathematical Specifications” book.

Symbol	Name	Description
a	semimajor axis	The semimajor contains information on the type and size of an orbit. If $a > 0$ the orbit is elliptic. If $a < 0$ the orbit is hyperbolic. $a = \infty$ for parabolic orbits.
e	eccentricity	The eccentricity contains information on the shape of an orbit. If $e = 0$, then the orbit is circular. If $0 < e < 1$ the orbit is elliptical. If $e = 1$ the orbit is parabolic. If $e > 1$ then the orbit is hyperbolic.
i	inclination	The inclination is the angle between the $\hat{\mathbf{z}}_I$ axis and the orbit normal direction $\mathbf{h}$. If $i \leq 90°$ then the orbit is prograde. If $i > 90°$ then the orbit is retrograde.
ω	argument of periapsis	The argument of periapsis is the angle between a vector pointing at periapsis and a vector pointing in the direction of the line of nodes. The argument of periapsis is undefined for circular orbits.
Ω	right ascension of the ascending node	Ω is defined as the angle between $\hat{\mathbf{x}}_I$ and $\mathbf{N}$ measured counterclockwise. $\mathbf{N}$ is defined as the vector pointing from the center of the central body to the spacecraft, when the spacecraft crosses the bodies equatorial plane from the southern to the northern hemisphere. Ω is undefined for equatorial orbits.
ν	true anomaly	The true anomaly is defined as the angle between a vector pointing at periapsis and a vector pointing at the spacecraft. The true anomaly is undefined for circular orbits.

11.3. Constant Values

- Equatorial Radius = 6378.136658
- Geocentric Constant of Gravitation (μ)= 398600.4418 ($km^3 . s^{-2}$)
- First zonal harmonics:
    - J2 = 0.0010826158
    - J3 = -0.00000253881
    - J4 = -0.00000165597
- Earth Nodal Precession (Ω_0) = 1.0027379093507951
- Rotational Speed of the Earth = $2.\pi \times \Omega_0 \times 1/86400$ ($rad.s^{-1}$)
- Earth Flatness = 1.0 / 298.26
- Reference Julian Day (TJ2000) = 2451545

11.4. Simple parameters

With:

n = $\sqrt{\mu/a^3}$

M = Mean Anomaly

MM = Mean Movement or Mean Motion provided by the TLE

11.4.1. AOL

Argument of Latitude or Position on Orbit is the angle from the ascending node to the satellite.

$$AOL = AOP + TA$$

11.4.2. ETFP

Elapsed time from periapsis (in minutes)

$$ETFP = \frac{M}{n} \times 60$$

11.4.3. NP

The **nodal precession** is the angular velocity of the node line around the poles axis (deg/day)

$$NP = \dot{\Omega} = \left(-\frac{3}{2(1-e^2)^2} \times n \times J2 \times \left(\frac{R}{a}\right)^2 \times \cos i\right) \times 86400$$

11.4.4. AP

The **apsidal precession** is the angular velocity of the apside line in the orbit plane (deg/day)

$$AP = \dot{\omega} = \left(\frac{3}{4(1-e^2)^2} \times n \times J2 \times \left(\frac{R}{a}\right)^2 \times (5\cos^2 i - 1)\right) \times 86400$$

11.4.5. Periods

With:

- Keplerian Period (in minutes):

$$Tk = \left(2\pi \times \sqrt{\frac{a^3}{\mu}}\right) / 60$$

- Secular Variation of the mean movement:

$$\frac{\Delta n}{n} = \frac{3}{4(1-e^2)^{\frac{3}{2}}} \times J2 \times \left(\frac{R}{a}\right)^2 \times (3\cos^2 i - 1)$$

- Secular variation or the AOP:

$$\frac{\dot{\omega}}{n} = \frac{3}{4(1-e^2)^2} \times J2 \times \left(\frac{R}{a}\right)^2 \times (5\cos^2 i - 1)$$

Anomalistic Period (apsidal period)**:**

$$Ta = 1 - \frac{\Delta n}{n} \times T$$

Draconitic Period (nodal period)**:**

$$Td = \frac{Ta}{1 + \frac{\dot{\omega}}{n}}$$

11.4.6. DL

The **Delta Longitude** is the angle/distance between each passing at the ascending node.

With:

Earth Nodal Precession: $\dot{\Omega}_T$ = 1.0027379093507951°/day

$$DL\,(°) = \left(\frac{360}{\left(\frac{MM \times 360 + \dot{\omega}}{\dot{\Omega}_T \times 360 - \dot{\Omega}}\right)}\right)$$

11.4.7. DREL

Relative Distance of the satellite

$$DREL = \frac{\sqrt{x^2 + y^2 + z^2}}{R}$$

11.4.8. GST

The **Greenwich Sideral Time** is the angle between the Greenwich meridian and the vernal axis.

$$epoch = epoch_{JD} = epoch_{MJD} + 2430000$$

$$\boldsymbol{if}\ epoch \geq int(epoch) + 0.5\ \boldsymbol{then}\ DU = int(epoch) + 0.5 - TJ2000$$
$$\boldsymbol{if}\ epoch < int(epoch) + 0.5\ \boldsymbol{then}\ DU = int(epoch) - 0.5 - TJ2000$$

$$TU = \frac{DU}{36525}$$

$$QG0 = \left(24110.54841 + \left(86400 \times \frac{36525}{365.2421897} \times TU\right) + (0.093104 \times TU^2) - (0.0000062 \times TU^3)\right)$$

$$\boldsymbol{if}\ epoch < int(epoch) + 0.5\ \boldsymbol{then}\ DJ = epoch - (int(epoch) - 0.5)$$
$$\boldsymbol{if}\ epoch > int(epoch) + 0.5\ \boldsymbol{then}\ DJ = epoch - (int(epoch) + 0.5)$$

$$QGT = \left(QG0 + (86400 \times DJ \times \dot{\Omega}_T)\right)$$

$$GST = \left(\frac{QGT}{240}\right)$$

11.4.9. LAT/LNG

The **Latitude** of the satellite is calculated with an iterative method.
With:

$$r = \sqrt{(x^2 + y^2)}$$
$$lat0 = \tan^{-1}\left(\frac{z}{r}\right)$$
$$phi = 7.0$$
$$E2 = \frac{1}{298.26} \times \left(2 - \frac{1}{298.26}\right)$$

$$do\ while\ abs(lat0 - phi) > 0.0000001$$

$$phi = lat0$$
$$ct = \frac{1}{\sqrt{1 - E2 \times \sin^2(phi)}}$$
$$lat0 = \tan^{-1}\left(\frac{z + R \times ct \times E2 \times \sin(phi)}{r}\right)$$

The **Longitude** of the satellite is:

$$LNG = atan2(x, y) - GST$$

11.4.10. Altitudes, Velocities

With:

R = 6378.136658 *kms (Equatorial Earth Radius)*
$R_s = \|x, y, z\|$
$f = 0.003352806$

$$R_T = \frac{R}{\sqrt{\frac{cos^2(LAT) + sin^2(LAT)}{(1-f)^2}}}$$

(For Altitudes determination, the Earth radius used (Rt) is function of the earth flatness f)

$$\boldsymbol{APR} = SMA \times (1 + ECC)$$
$$\boldsymbol{PER} = SMA \times (1 - ECC)$$
$$\boldsymbol{APA} = APR - R_T$$
$$\boldsymbol{PEA} = PER - R_T$$
$$\boldsymbol{ALT} = R_s - R_T$$
$$\boldsymbol{MALT} = SMA - R$$

$$\boldsymbol{APV} = \sqrt{\mu \times \left(\frac{2}{APR} - \frac{1}{SMA}\right)}$$
$$\boldsymbol{PEV} = \sqrt{\mu \times \left(\frac{2}{PER} - \frac{1}{SMA}\right)}$$
$$\boldsymbol{VEL} = \sqrt{\mu \times \left(\frac{2}{R_s} - \frac{1}{SMA}\right)}$$

11.4.11. LST

The **Local Sideral Time** is the angle between the local meridian and the vernal axis

$$LST = LNG + GST$$

11.4.12. Eclipse

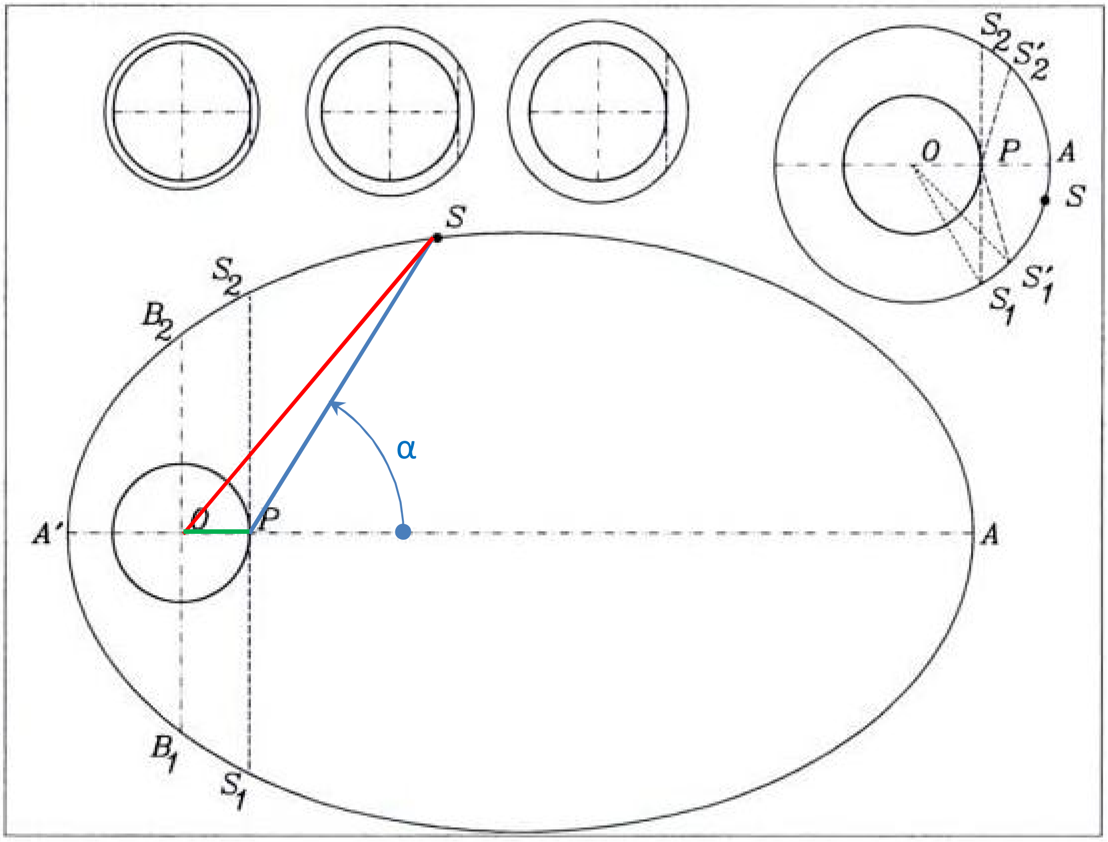
With:

$$ANGLEX = \cos^{-1}\left(\frac{\overrightarrow{x, y, z}}{\|x, y, z\|} \cdot \left(-\frac{\overrightarrow{xs, ys, zs}}{\|xs, ys, zs\|}\right)\right)$$

$$ANGLEX0 = \sin^{-1}\left(\frac{1}{DREL}\right)$$

$$\boldsymbol{if}\ ANGLEX < ANGLEX0\ \boldsymbol{then}\ Eclipse = \boldsymbol{true}$$

11.4.13. Station visibility



For both circular and elliptic orbit, the maximum visibility range used by TLE Analyser is when α=90°. Depending of the satellite position, α is calculated as following:

$$\overrightarrow{OS} = \begin{bmatrix} Xsat \\ Ysat \\ Zsat \end{bmatrix} = (R + ALT) \times \begin{bmatrix} \cos LAT_{sat} \times \cos LNG_{sat} \\ \cos LAT_{sat} \times \sin LNG_{sat} \\ \sin LAT_{sat} \end{bmatrix}$$

$$\overrightarrow{OP} = \begin{bmatrix} Xsta \\ Ysta \\ Zsta \end{bmatrix} = R \times \begin{bmatrix} \cos LAT_{sta} \times \cos LNG_{sta} \\ \cos LAT_{sta} \times \sin LNG_{sta} \\ \sin LAT_{sta} \end{bmatrix}$$

$$\overrightarrow{PS} = \frac{\overrightarrow{OS} - \overrightarrow{PA}}{\left\| \overrightarrow{OS} - \overrightarrow{PA} \right\|}$$

$$\alpha = \cos^{-1}\left(\overrightarrow{PS}.\overrightarrow{OP}\right)$$

12. SGP4 and SDP4 models

SGP4 model was developed by Cranford in 1970 and is actually used for Low Earth Orbit determination (with period lower than 225 minutes).

The following example shows the difference between the real SGP4 model and TLE Analyser:

```
1 88888U          80275.98708465  .00073094  13844-3  66816-4 0     8
2 88888  72.8435 115.9689 0086731  52.6988 110.5714 16.05824518   105

TLE Epoch: 01/10/1980 23:41:24.000 (UTC)
```

Parameters	SGP4 Model*	TLE ANALYSER	
x	2328.970	2328.970	*km*
y	-5995.221	-5995.221	*km*
z	1719.971	1719.973	*km*
$\dot{x}$	2.91207	2.91207	*Km/s*
$\dot{y}$	-0.98341	-0.98341	*Km/s*
$\dot{z}$	-7.09081	-7.09081	*Km/s*

SDP4 model was developed by Hujsak in 1979 and is used for high altitude orbits (with period above 225 minutes).

The following example shows the difference between the real SDP4 model and TLE Analyser:

```
1 11801U          80230.29629788  .01431103  00000-0  14311-1 0     0
2 11801  46.7916 230.4354 7318036  47.4722  10.4117 2.28537848   000

TLE Epoch: 17/08/1980 07:06:40.000 (UTC)
```

Parameters	SDP4 Model*	TLE ANALYSER	
x	7473.371	7473.371	*km*
y	428.953	428.947	*km*
z	5828.748	5828.748	*km*
$\dot{x}$	5.10715	5.10715	*Km/s*
$\dot{y}$	6.44468	6.44468	*Km/s*
$\dot{z}$	-0.18613	-0.18613	*Km/s*

* Source from “SpaceTrack Report n°3 - Models for Propagation of NORAD Element Sets”
http://www.celestrak.com/NORAD/documentation/spacetrk.pdf

End of the document.