# TN044

# Planning Tool Simulator

## Document Control

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# 1 Introduction

## 1.1 Scope

In TN011 of the SWIRLS project, [MCSR], a study was conducted to assess whether the GLONASS constellation was needed from the user point of view, to guarantee, together with GPS and Galileo, enough satellite visibility to reach centimetre precision. For this purpose, it was developed a simulator, named MultiConstellation Simulator (MCS), which considered a single user-receiver and different combinations of constellations.

In the context of Real Time Kinematics (RTK) and Differential Global Navigation Satellite System (DGNSS), it is relevant to compute the visibility, not only of the user-receiver, but also of a network of stations, which constantly provides the user with corrections to its position. Moreover, it is important to guarantee that both the network and the user share a minimum satellite visibility for a sufficiently long period of time.

For this purpose, a Planning Tool Simulator (PTS) is now developed using MCS software functions. PTS simulates a tool that can be used in mission planning by DGNSS users, supporting several forms of analysis to determine visibility for GPS, GLONASS and Galileo satellites.

## 1.2 Applicability

This document is elaborated in the scope of the SWIRLS project, regarding the simulator transmitter and receiver analysis: WP6210.

## 1.3 Document Overview

Section 1 Defines the purpose, context and contents of this document
Section 2 Describes the planning tool development
Section 3 Presents a quick guide to the tool
Section 4 Illustrates an example of running a simulation
Section 5 Provides the conclusion

## 1.4 Abbreviations

| Abbreviation | Description |
|---|---|

| | |
|---|---|
| DGNSS | Differential Global Navigation Satellite System |
| DOP | Dilution of Precision |
| ECEF | Earth Centre Earth Fixed |
| ENU | East-North-Up |
| ESG | Enhanced Signal Generator |
| GNSS | Global Navigation Satellite Systems |
| GPS | Global Positioning System |
| GUI | Graphical User Interface |
| HDOP | Horizontal Dilution of Precision |
| MCS | MultiConstellation Simulator |
| PTS | Planning Tool Simulator |
| RTK | Real Time Kinematics |
| TOW | Time-Of-Weeks |

# 1.5 References

## 1.5.1 Applicable Documents

The applicable documents are listed in the following table.

| AD | Title | Reference number | Ver. | Date |
|---|---|---|---|---|
| [SoW] | Statement of Work | FP6-PRP-SSN-GPRD-R-003 | 1.8 | 01-Jan-2006 |

**Table 1-1: Applicable Documents**

## 1.5.2 Reference Documents

The reference documents are listed in the following table.

| RD | Title | Reference number | Ver. | Date |
|---|---|---|---|---|
| [MCSR] | MultiConstellation Simulation Results | FP6SWI-TN-011 | 1.1 | 28-May-2007 |
| [SUM] | Simulator User Manual | FP6SWI-TN-010 | 1.0 | 18-May-2006 |

**Table 1-2: Reference Documents**

# 2 Planning Tool Simulator Development

The MultiConstellation Simulator (MCS) tool provides satellite visibility for a single user-receiver only. MCS implementation is based on the Enhanced Signal Generator (ESG) application, whose user manual is presented in [SUM]. The development of the Planning Tool Simulator (PTS) focuses on the expansion of the MCS to more stations/ user. In this scope, an incremental approach is adopted, where the MCS tool is used in a recursive fashion: once for the user-receiver and once for each station. For a detailed MCS implementation description, please confer [MCSR].

This section describes the development of the PTS.

## 2.1 Requirements

In order to fulfil the aims described in §1, namely to develop a tool that provides the capability to analyze the combined visibility of a configurable number of receivers from availability and accuracy point of view, the requirements listed in Table 2-1 were derived. Some of the modules of the MCS and ESG software were reused.

| Requirement Title | Requirement Text |
|---|---|
| Supported Constellations | The simulation tool shall support the following constellations:<br>- GPS;<br>- GALILEO;<br>- GLONASS. |
| Constellations combinations | The simulation tool shall be able to simulate any combination of the constellations supported, e.g. GPS + GLONASS, GALILEO only, GPS + GLONASS + GALILEO. |
| User Position | The simulation tool shall be able to simulate the user position. |
| Multi-station | The simulation tool shall be able to select a subset of a fixed set of four stations (with preconfigured location). |
| DOP | The simulation tool shall be able to compute the Dilution Of Precision parameters using all satellites in view. |
| Visible satellites | The simulation tool shall be able to compute the number of visible satellites to all stations and user, within a simulation. |
| Mask angles | The simulation tool shall be able to generate and use masking profiles for open areas and urban canyons, independently for the user and each station. |
| Elevation and Azimuth | The simulation tool shall be able to compute the elevation and azimuth of each satellite visible to the user. |
| Plots | The simulation tool shall be able to provide the following plots: |

| Requirement Title | Requirement Text |
|---|---|
| | - HDOP values variation in time domain;<br>- Number of visible satellites to the user-receiver and to the multi-station;<br>- Period of visibility of each satellite to the user-receiver and to the multi-station;<br>- Sky plot of the visible satellites to the user;<br>- Ground track. |
| Reports | The simulation tool shall be able to provide the following reports:<br>- Azimuth angle of each visible satellite, per time interval;<br>- Elevation angle of each visible satellite, per time interval;<br>- HDOP values per time interval;<br>- Visible satellites per time interval. |
| Load Ephemerides | The simulation tool shall be able to load ephemerides in the following format:<br>- YUMA<br>- RINEX2 |

**Table 2-1: Requirements for the Simulation Tool**

## 2.2 Architecture

In MCS, the satellite positions of the selected constellations are computed followed by the user-satellite geometry, which allows detecting the satellites that are visible to the user and computing DOP.

PTS is developed using the MCS main software modules recursively. The high level architecture of PTS is depicted in Figure 2-1.

The software comprises a Graphical User Interface (GUI) that allows the user to load ephemerides from file and to configure the parameters for a specific mission planning simulation. These parameters include the simulation time, the selection of plots and reports to output, the selection of the constellations to be used, the receiver's position and masking profile, the selection of the stations to be used and the respective masking profiles.

Once the parameters have been configured, the simulation starts and the MCS software runs once for the receiver and once for each selected station. In this way the planning tool simulator is able to compute the data needed, avoiding increasing the complexity of MCS.

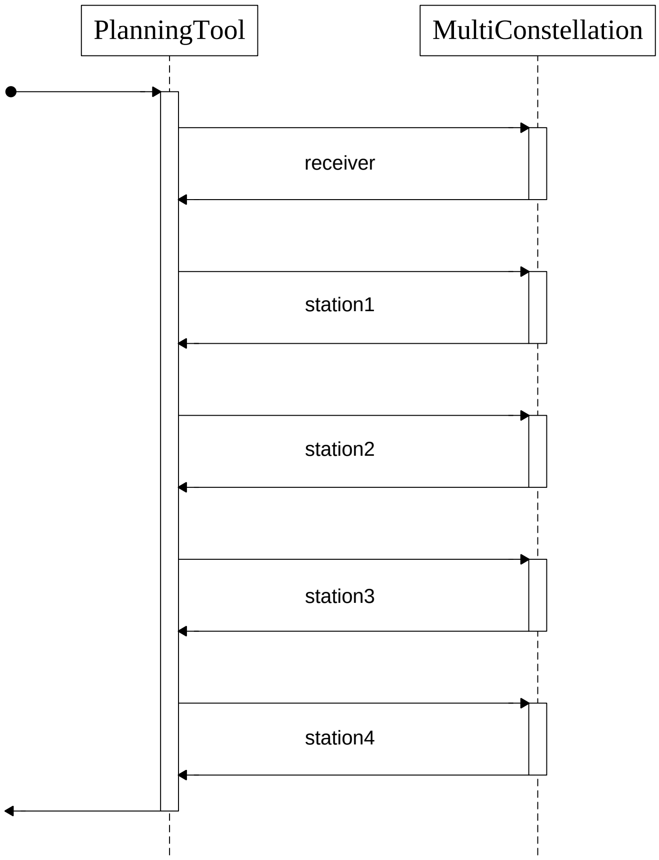


**Figure 2-1: PTS sequence diagram**

## 2.3 Implementation

A modular approach is adopted for the software implementation allowing flexibility and reusing of the modules of the MCS and the ESG software (*cf.* [MCSR]).

The list of software functions that implement the PTS software in MATLAB® is given in Table 2-2; each function is provided with a description.

| Software Function | Description |
| --- | --- |
| CompVisMask | Computes and stores the masking profiles according to the configurable parameters inserted by the user in the GUI. Elevation and azimuth angle pairs are mapped to acceptable ranges. This function is called upon initialization of the software in order to compute the default parameters and upon user request in the GUI. In the latter, the results obtained are plotted. |

| Software Function | Description |
|---|---|
| CONST_ecef | Computes the satellites position in ECEF coordinates given a set of ephemerides, which are stored previously in a .mat file, for all three constellations. |
| DeleteEphemerids | Called when loading ephemerides: deletes the default ephemerides and updates visibility mask. |
| DynMain | This function is responsible for assessing the visibility of all satellites with respect to the user/ station. For that purpose, it computes the elevation and azimuth angles, eliminates the required satellites based on the masking profile. Finally, it computes the DOP values. |
| editUser | Generates the GUI where the user redefines the receiver location to be used in the simulation; moreover, it enables the masking profile GUI where the user can select a masking profile for the receiver location. |
| editStations | Accessible upon selection of one or more stations, it generates the GUI where the user redefines the stations locations to be used in the simulation; moreover, it enables the masking profile GUI where the user can select a masking profile for the location of each previously selected station. |
| FillWithBlanks | Creates a string of blanks with size given by the difference of the input size and the length of the preceding string. |
| GetDops | Computes the GDOP, VDOP, HDOP, PDOP and TDOP based on the observation matrix that consists of the LOS vectors of the satellites positions with respect to the stations. |
| LoadEphemerids | Loads new ephemerides previously read to a temporary file, and overwrites the old ephemerides with the new saving them to file 'EPH.mat'. |
| MakeAzElevTable | Called while making the elevation and azimuth reports, it constructs tables with the elevation and azimuth values per satellite and per time interval. |
| MakeVisibTable | Called while making the visibility report, it constructs a table with the visible satellite labels per time interval. |
| maskingProfile | Generates the GUI where the user defines the masking profiles, for either the location of each previously selected station or the location of the receiver. |
| NAV_calcZcount | Computes the GPS time (TOW and leap seconds) given a date in the format [year month day hour minute second]. |
| Planning | Manages the calls to the other functions and assures the operational sequence of the software. It is the main software function. |

| Software Function | Description |
|---|---|
| Plantool | Generates the main GUI; it calls the SetParameters function which initializes all the parameters. |
| Plots | Called in the end of the simulation, it plots the user pre-configured information using the results stored during the simulation. |
| ReadRinex2 | Reads a RINEX2 Navigation Message file and reformats the data into a matrix with one column for each ephemeris and a row for each satellite. |
| ReadYuma | Reads a text file YUMA almanac, saves it and returns a success flag. |
| Reports | Called in the end of the simulation, it reports the user pre-configured information using the results stored during the simulation. |
| RemoveBlanks | Creates a string of blanks with specified size. |
| Sec2Hms | Converts a string of seconds into the format: *hh:mm:ss*. |
| SetParameters | Called at GUI launching, it is responsible for initializing the parameters. |
| SetYuma | Formats an input YUMA file to a certain standard, overwriting the original file. |
| setPlots | Generates the GUI where the user selects the plots that the tool should output. |
| setReports | Generates the GUI where the user selects the reports that the tool should output. |
| StoreConstData | Run in pre-processing phase; it stores the ephemerides to be applied for the current simulation. |
| TimeLabels | Creates a time labels matrix for plotting purposes. |
| TimeVect | Creates a matrix such that the lines are strings of information to be printed into a report. |
| TwoDigitsStr | Converts a string with a number from 0 to 9 into a string of two digits by adding a 0 before that digit. |
| UTIL_date2jday | Converts a date in the format [year month day hour minute second] into the Julian day. |
| UTIL_ecef2enu | Converts a vector in ECEF coordinates to ENU coordinates. |
| UTIL_ecef2gd | Converts a vector in ECEF coordinates to geodetic coordinates [LAT LON ALT]. |
| UTIL_gd2ecef | Converts a vector in geodetic coordinates to ECEF coordinates. |
| WriteReports | Contains the functions responsible for creating and writing the user configurable data to file *.txt*. |

**Table 2-2: List of Software Functions**

# 3 Quick Guide

This section describes the PTS software organization and the system environment, and gives instructions on how to run the application.

## 3.1 Software Organization

The development of 34 software functions is proposed in order to implement the architecture presented in the previous sections. These functions are divided into three different groups as depicted in the following figure: gui, src and utils.

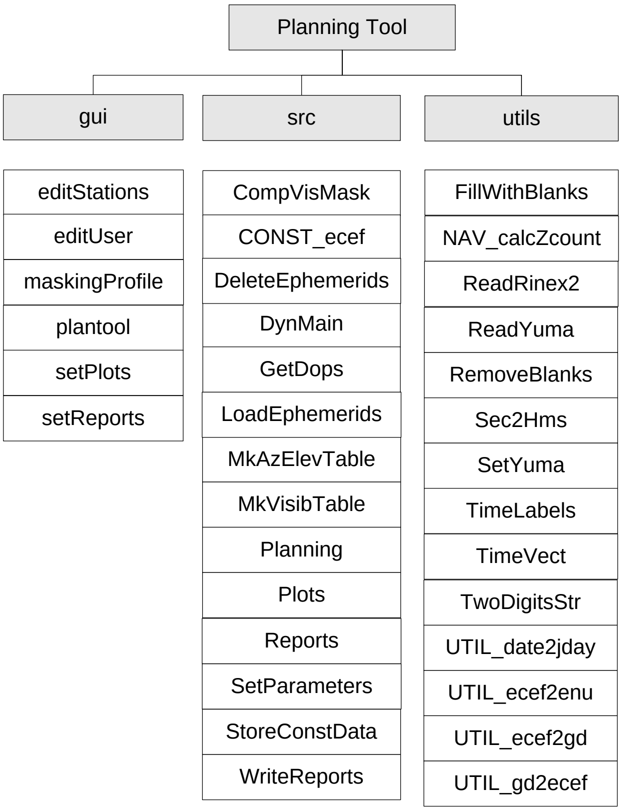


**Figure 3-1: Software Component Hierarchy**

The gui group includes all the functions responsible for generating the GUI.

The src group includes the source code of all software functions that are used to implement the simulator.

The utils group includes the functions that are developed to support the software execution.

## 3.2 System Environment

The data files organization relative to the planning tool simulator module is depicted in Figure 3-2, where the shaded blocks account for folders that contain the files needed.

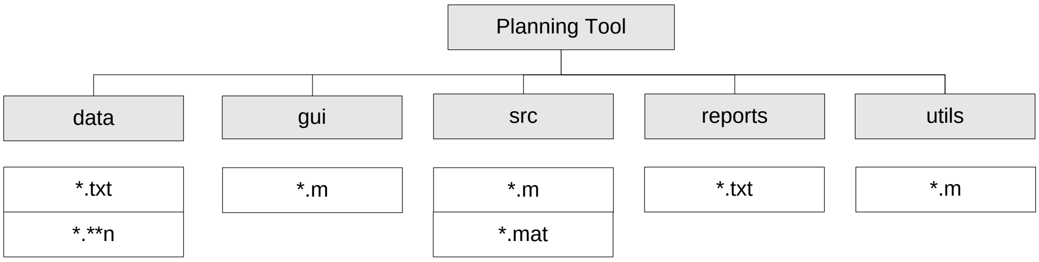


**Figure 3-2: System Environment**

All files required to run the PTS module are under the folder named "Planning Tool". This folder contains five subfolders that follow the philosophy of the software components division as presented in Figure 3-1.

Accordingly, the organization of the source code MATLAB® files with suffix ".m", suggest three main folders: "gui", "src" and "utils".

Additionally, there are two subfolders within "Planning Tool": "reports" and "data". The "reports" folder contains four report files generated by the PTS, namely Azimuth angles, HDOP, Elevation angles and Visibility reports. In each simulation the user can choose which reports to output; for each chosen report, the tool will then save a file with a standard report type name, overwriting any report file that might exist with the same name in that folder. These files have extension ".txt". The "data" folder is a user managed storage folder, placed to contain all the YUMA and RINEX2 files which are to be loaded by PTS. Therefore, the files expected in this folder have the extensions ".txt" and ".**n".

## 3.3 Initiating the Planning Tool Simulator

In order to run the planning tool simulator, one has to perform the following steps:

1. Launch the MATLAB® environment, version 7.0 with no extra toolbox;
2. Set the path of the MATLAB® environment to the "Planning Tool" main folder;
3. Set the path in the current directory to the "Planning Tool" main folder;
4. Type in the command line the following instruction: "plantool";

The main menu pops up, where the user can set the parameters and run simulations.

# 4 A Case Example

This section describes, step by step, an example of running a simulation. The simulation is designed to use as many features of the tool as possible, in order to give a broad insight of it.

## 4.1 The Scenario

Assume a fictitious network composed of four reference stations and one user-receiver, used for instance, for purposes of DGNSS. Suppose the stations form a perfect square and the user-receiver is placed in the geometric centre of the network. Figure 4-1 depicts this scenario.

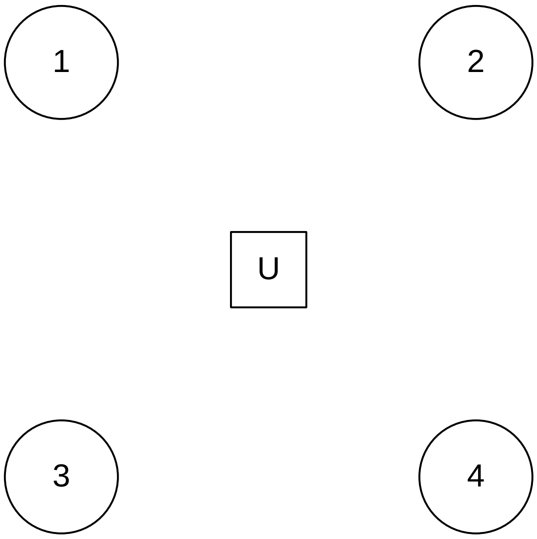


**Figure 4-1: Diagram of the network**

The parameters listed in Table 4-1 below are drawn to model the network configuration described in Figure 4-1. In addition it includes masking profiles for the stations and the user in order to simulate different environments in terms of availability and accuracy.
Two types of environments are considered: open areas and urban canyons. Open areas are specified by user configurable elevation and azimuth masks, and by an elevation mask angle, determining the limit below which, satellites are not visible. Urban Canyons are common environments for a GNSS user; herein they are modelled through the length and the width of the canyon (*e.g.* a street), and by the height of the obstacles (*e.g.* buildings) surrounding it. Furthermore, it enables to shift the masking profile, *i.e.* to rotate the profile with respect to the specified azimuth angle. As with Open Areas, it is also possible to specify an elevation mask angle.

The simulation described in the remainder of this section is based on these parameters.

| Parameter | Value |
|---|---|
| Constellations | GPS + GAL + GLO |
| Number of Stations | 4 |
| User Position: | |
| ▪ Latitude (DMS) | 45° 00´ 00´´ N |
| ▪ Longitude (DMS) | 10° 00´ 00´´ W |
| ▪ Altitude (wrt the Mean Sea level) | 10 m |
| User Masking Profile: | |
| ▪ Profile | Urban Canyon |
| ▪ Canyon Height | 15 m |
| ▪ Canyon Width | 20 m |
| ▪ Canyon Length | 100 m |
| ▪ Shift Profile Angle | 90° |
| ▪ Elevation Mask | 15° |
| Station 1 Position: | |
| ▪ Latitude (DMS) | 60° 00´ 00´´ N |
| ▪ Longitude (DMS) | 25° 00´ 00´´ W |
| ▪ Altitude (wrt the Mean Sea level) | 10 m |
| Station 1 Masking Profile: | |
| ▪ Profile | Open Area |
| ▪ Azimuth Mask Direction | 90° |
| ▪ Azimuth Mask Amplitude | 10° |
| ▪ Elevation Mask | 15° |
| Station 2 Position: | |
| ▪ Latitude (DMS) | 60° 00´ 00´´ N |
| ▪ Longitude (DMS) | 5° 00´ 00´´ E |
| ▪ Altitude (wrt the Mean Sea level) | 10 m |
| Station 2 Masking Profile: | |
| ▪ Profile | Open Area |
| ▪ Azimuth Mask Direction | 0° |
| ▪ Azimuth Mask Amplitude | 0° |
| ▪ Elevation Mask | 15° |
| Station 3 Position: | |
| ▪ Latitude (DMS) | 30° 00´ 00´´ N |
| ▪ Longitude (DMS) | 25° 00´ 00´´ W |
| ▪ Altitude (wrt the Mean Sea level) | 10 m |
| Station 3 Masking Profile: | |
| ▪ Profile | Open Area |
| ▪ Azimuth Mask Direction | 0° |
| ▪ Azimuth Mask Amplitude | 0° |
| ▪ Elevation Mask | 10° |

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E-mail: fp6@septentrio.com

| Parameter | Value |
|---|---|
| Station 4 Position:<br>▪ Latitude (DMS)<br>▪ Longitude (DMS)<br>▪ Altitude (wrt the Mean Sea level) | <br>30º 00´ 00´´ N<br>5º 00´ 00´´ E<br>10 m |
| Station 4 Masking Profile:<br>▪ Profile<br>▪ Azimuth Mask Direction<br>▪ Azimuth Mask Amplitude<br>▪ Elevation Mask | <br>Open Area<br>0º<br>0º<br>15º |
| Start Time | 10-December-2007 09:00:00 |
| Simulation Time (seconds) | 86400 |
| Time Step (seconds) | 600 |

**Table 4-1: Simulation Parameters**

# 4.2 General Options

After executing the actions described in §3.3 the main menu pops up.

In the main menu, the user can perform the following actions:

- Select which constellations to use;
- Select the stations;
- Configure time (starting time, simulation time and time step);
- Access to other menus such as ‘‘setPlots’’ and ‘‘editStations’’ menus;
- Access a browser to select an ephemerides file to load.

Figure 4-2 exhibits PTS main menu with the simulation parameters already inserted.

**Figure 4-2: PTS Main Menu**

From the main menu it is always possible to access the "Load YUMA/RINEX" browser, where the user can select either a YUMA or a RINEX2 formats file of to be loaded. This action implies that the default ephemerides, loaded at startup, are replaced by the new ones for the respective constellations only. Figure 4-3 depicts this browser. Moreover, these files are required to be stored inside the *data* folder.

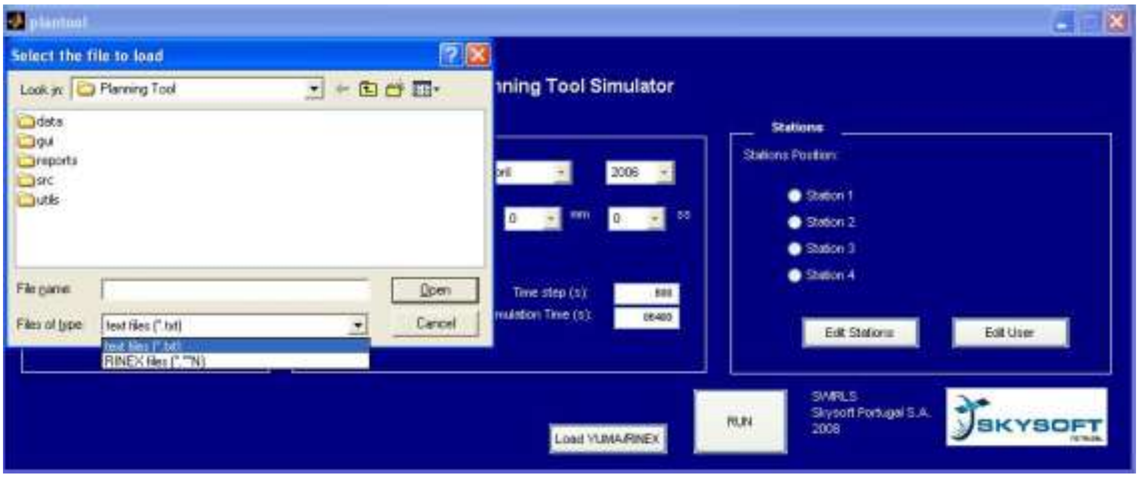



**Figure 4-3: Load YUMA/RINEX browser**

If the YUMA or RINEX2 file is successfully read then, one of the following messages pops-up. If instead, a file which is not in a recognizable format, that is if it does not respect the widely spread definition of an YUMA almanac or of the RINEX2 format, then an error message pops-up.


**Figure 4-4: Loading YUMA/RINEX dialog boxes**

Figure 4-5 depicts the ''Edit User'' menu, accessible from the main menu; it is where the user configures parameters related with the user-receiver's profile, namely its location and masking profile. Similar to the ''Edit User'' menu, the ''Edit Stations'' menu (Figure 4-6) is also accessible from the main menu; accordingly, it enables the user to configure the stations profile.

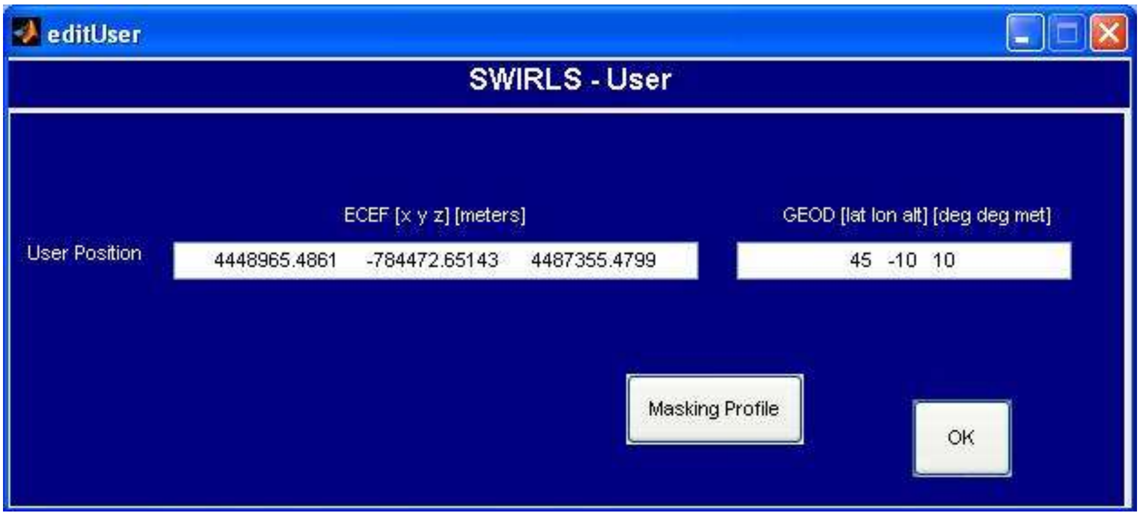



**Figure 4-5: Edit User menu**


**Figure 4-6: Edit Stations Menu**

Accessible from both the "Edit User" and the "Edit Stations" menus, the "Masking Profile" menu is where the user configures the user-receiver and the stations profile, respectively. An example of this menu is presented in Figure 4-7; it includes the parameters from Table 4-1.

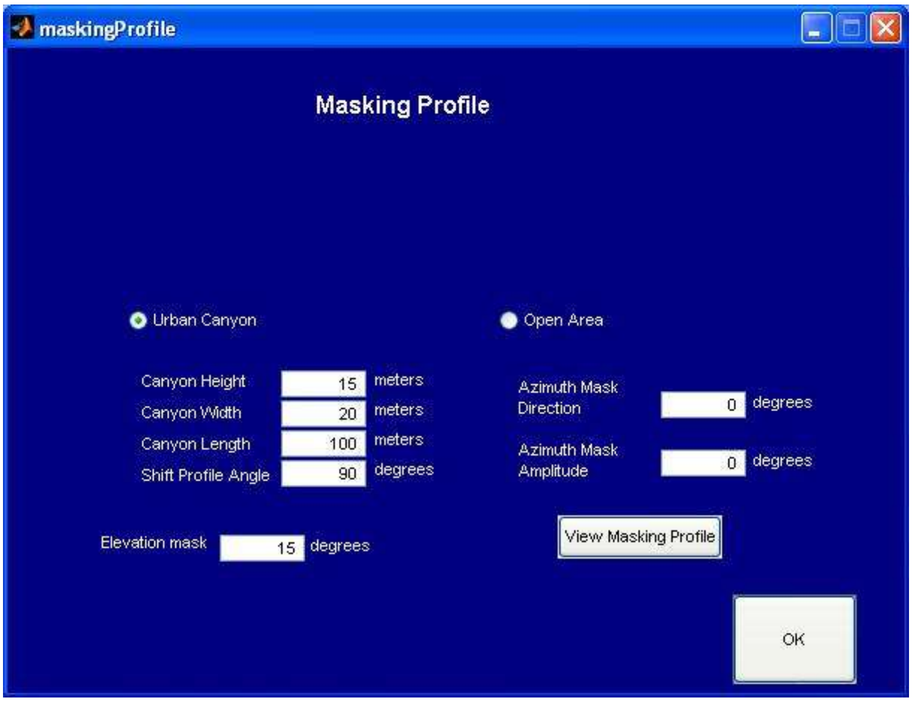



**Figure 4-7: User Masking Profile menu**

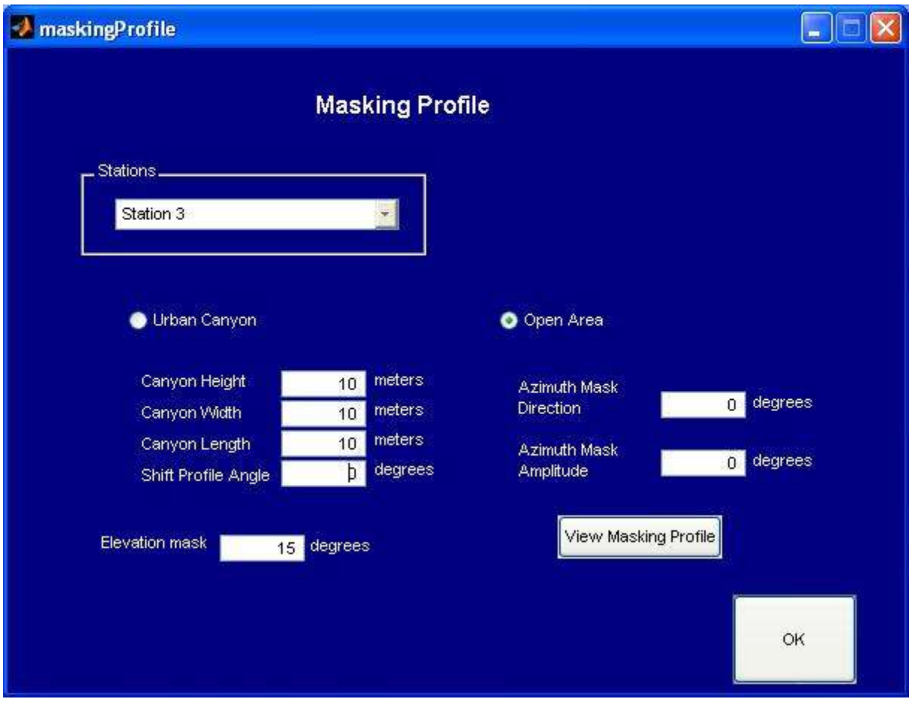



**Figure 4-8: Stations Masking Profile menu**

# 4.3 User Environments

In addition, from these menus it is possible to visualize the masking profiles in a plot such that for each azimuth angle it gives the elevation angle. Satellites below this line are considered as not visible to the user/station and therefore they are eliminated from the range of available satellites.

The user can choose between two different types of environment: urban canyons and open areas. Each type is characterised by a set of parameters, which generate several different profiles.

Urban Canyons are a typical type of environment for a GNSS user since they present non homogeneous masking profiles. The adopted model in the software implementation takes into account the length and width of the canyon, herein considered to be a street, as well as the height of the buildings or the obstacles that surround it. It is also possible to shift the profile.

Figure 4-9 depicts the user masking profile which is an East-West oriented, 20 meters wide street with 100 meters length and with buildings assumed to be 15 meters high.

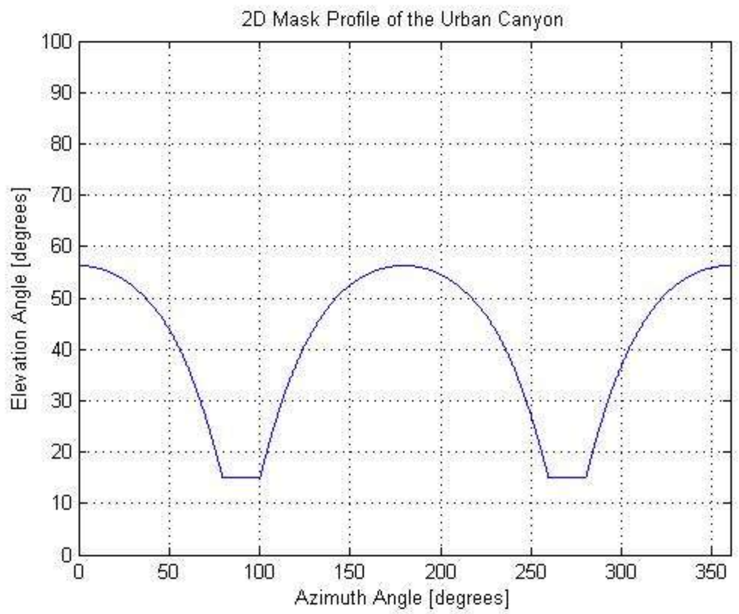



**Figure 4-9: User Masking Profile graph**

Open areas are specified by user configurable elevation angle, azimuth direction and shadowing amplitude. Furthermore, when combining both masks, the goal is to point to the worst situation. Station 1 gives an example of a masking profile of an open area environment with an elevation mask of 15 degrees and shadowing in an azimuth direction of 90 degrees with amplitude of 10 degrees and is depicted in Figure 4-10.

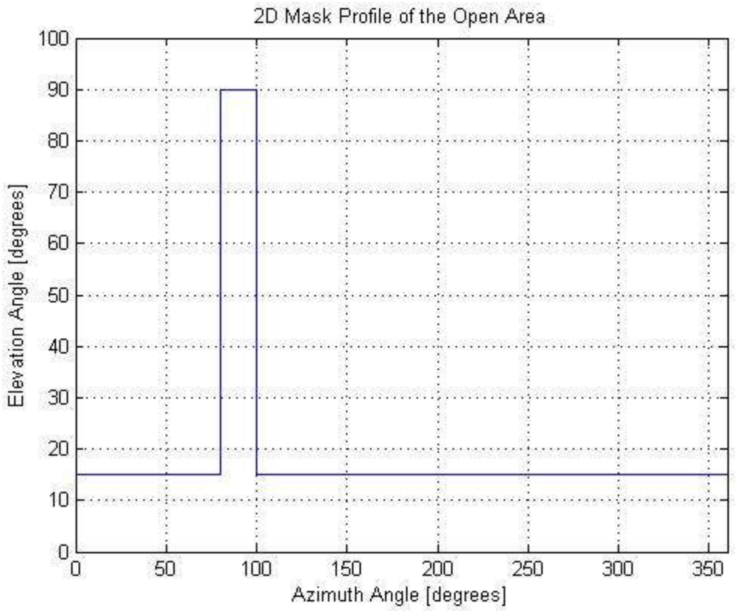



**Figure 4-10: Station 1 Masking Profile graph**

# 4.4 Output

## 4.4.1 Graphical Output

At the end of a simulation, the following data can be output in a graphical form:

- Ground Tracking;
- DOP values for the user-receiver's location;
- Sky plot for the user-receiver's location;
- Number of satellites visible simultaneously from the user-receiver's location and the selected stations location;
- Simultaneous satellite period of visibility from the user-receiver's location and the selected stations location;

The following figure depicts the menu where the user selects the plots to output.

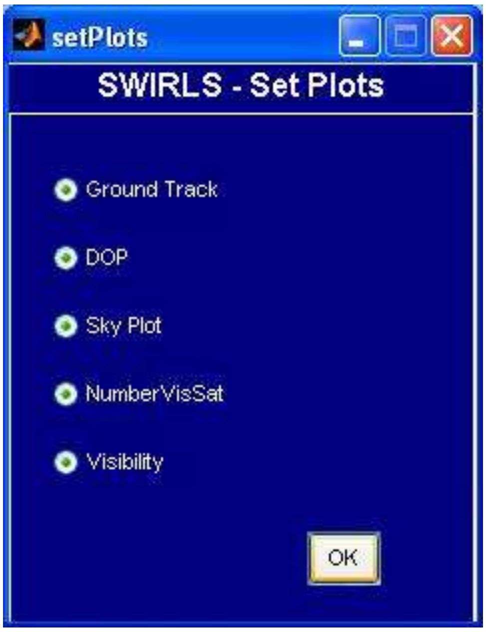



**Figure 4-11: Set Plots menu**

Having had configured all aspects, the simulation starts and a progress dialog box appears, as depicted by Figure 4-12.

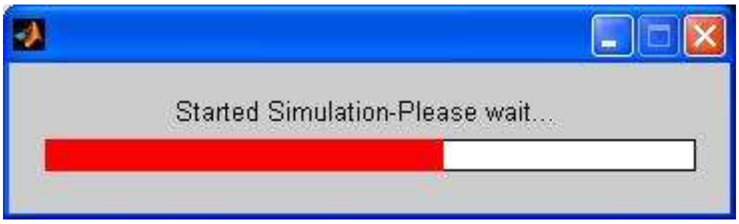



**Figure 4-12: "Simulation running" dialog**

The ground track is plotted only for the first PRN of each activated constellation. Figure 4-13 depicts the ground track for GPS, Galileo and GLONASS PRN 1 satellites.

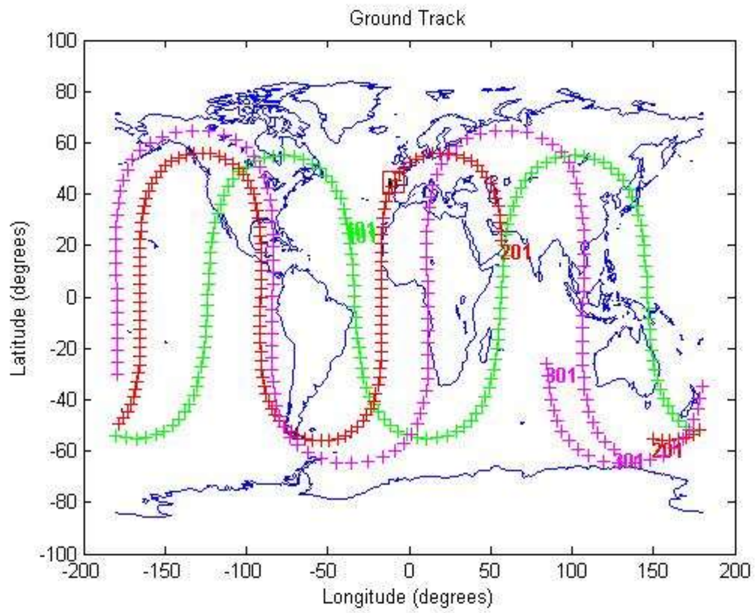



**Figure 4-13: Ground Track graph**

Figure 4-14 shows the HDOP for the parameters of Table 4-1. The HDOP corresponds to the user HDOP, *i.e.* it is independent of the selected stations (if any).

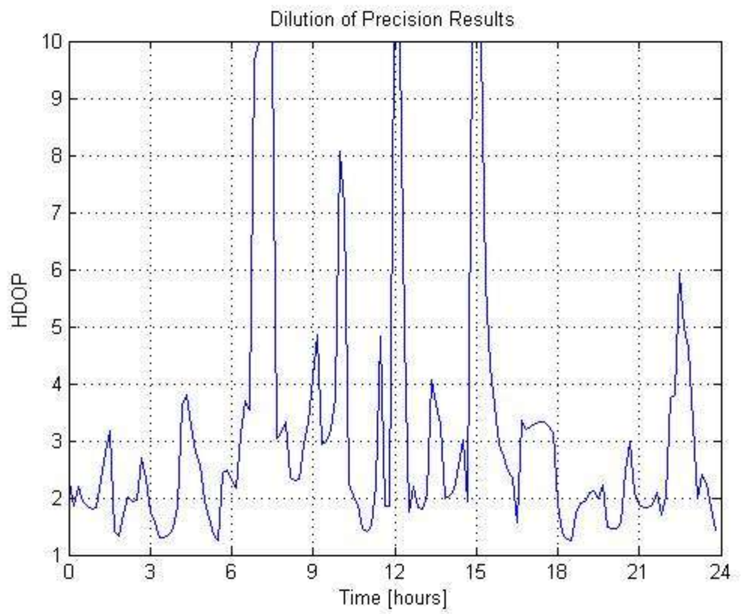



**Figure 4-14: DOP graph**

Figure 4-15 shows the user's sky plot for the parameters of Table 4-1.

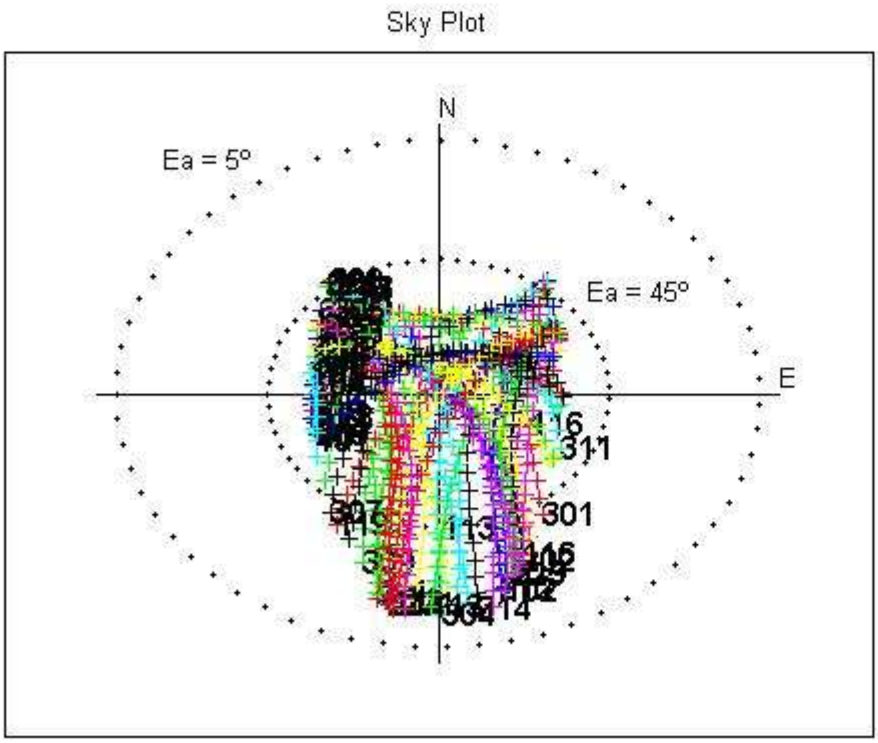



**Figure 4-15: Sky Plot graph**

Figure 4-16 shows the number of visible satellites plot from the user position and, simultaneously, from the stations position, for the parameters of Table 4-1.

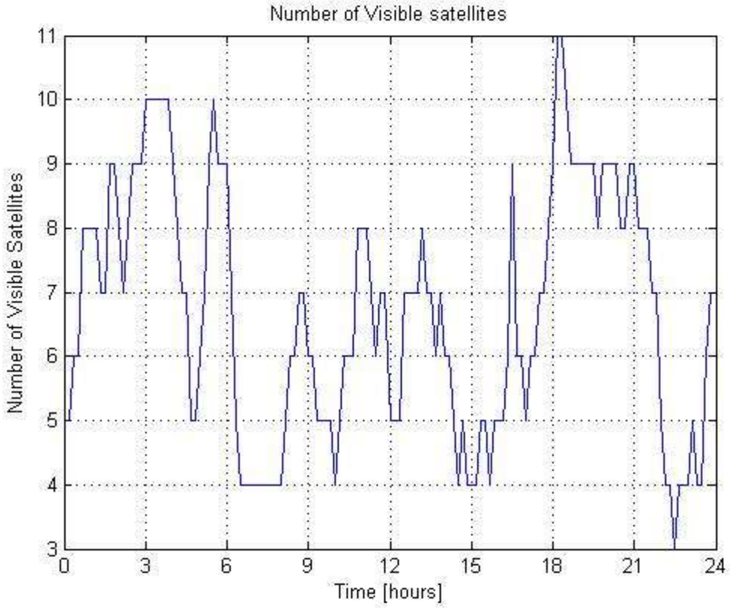



**Figure 4-16: Number of Visible Satellites graph**

Figure 4-17 shows the period of visibility chart of the user position and, simultaneously, of the stations position, for the parameters of Table 4-1.

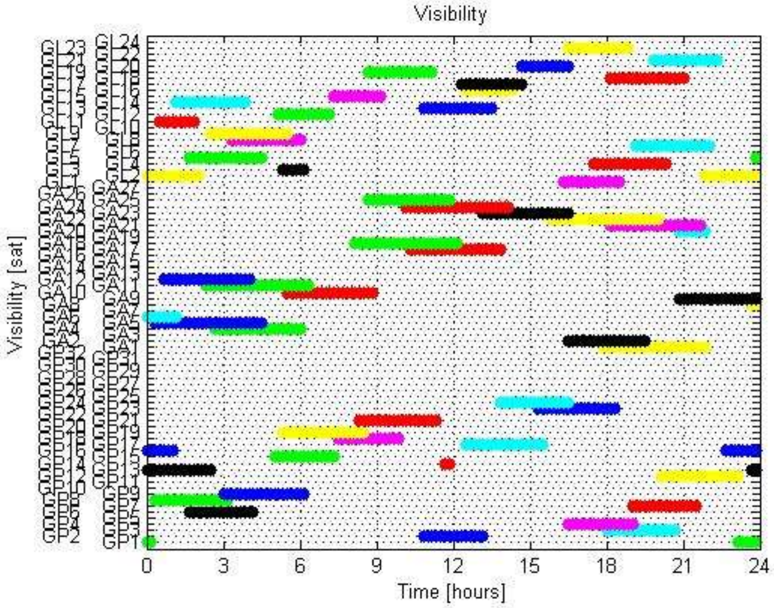



**Figure 4-17: Availability chart**

### 4.4.2 Reports

In addition, the following reports can be output to file:

- Azimuth per visible satellite and per time period;
- HDOP per time period, for the user-receiver's location only;
- Elevation angle per visible satellite and per time period, for the user-receiver's location only;
- Visible satellites, simultaneously to the user-receiver's location and the selected stations location, per time period;

Figure 4-18 depicts the menu where the user selects the reports to output.

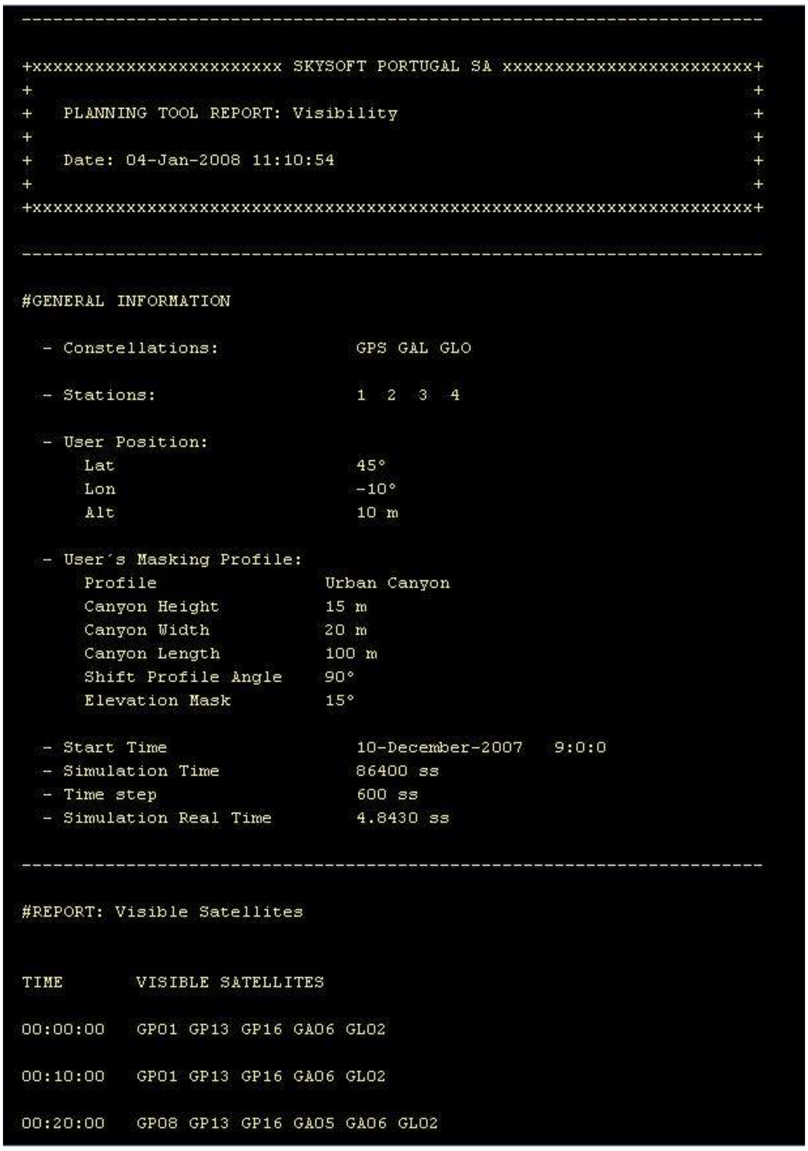

**Figure 4-18: Set Reports menu**

Each report is structured in three parts:

1. A header: identifies the type of report, the date and time;
2. General Information: lists general information about the simulation such as the constellations used, the user position or the simulation time;
3. Data: lists the data of the report, according to the type.

Figure 4-19 depicts an excerpt of a report where the three parts can easily be identified.

The last four figures constitute examples of the different data reports.



```
-----------------------------------------------------------------------

+xxxxxxxxxxxxxxxxxxxxxxxxx SKYSOFT PORTUGAL SA xxxxxxxxxxxxxxxxxxxxxxxxx+
+                                                                       +
+   PLANNING TOOL REPORT: Visibility                                    +
+                                                                       +
+   Date: 04-Jan-2008 11:10:54                                          +
+                                                                       +
+xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx+

-----------------------------------------------------------------------

#GENERAL INFORMATION

  - Constellations:            GPS GAL GLO

  - Stations:                  1  2  3  4

  - User Position:
      Lat                      45°
      Lon                      -10°
      Alt                      10 m

  - User´s Masking Profile:
      Profile               Urban Canyon
      Canyon Height         15 m
      Canyon Width          20 m
      Canyon Length         100 m
      Shift Profile Angle   90°
      Elevation Mask        15°

  - Start Time                 10-December-2007   9:0:0
  - Simulation Time            86400 ss
  - Time step                  600 ss
  - Simulation Real Time       4.8430 ss

-----------------------------------------------------------------------

#REPORT: Visible Satellites


TIME       VISIBLE SATELLITES

00:00:00   GP01 GP13 GP16 GA06 GL02

00:10:00   GP01 GP13 GP16 GA06 GL02

00:20:00   GP08 GP13 GP16 GA05 GA06 GL02
```

**Figure 4-19: A Report**

------------------------------------------------------------------------

#REPORT: Azimuth Angles (degrees)

| p. 01/24 | 00:00:00 | 00:10:00 | 00:20:00 | 00:30:00 | 00:40:00 | 00:50:00 |
|---|---|---|---|---|---|---|
| GP01 | 243.2613 | 236.2986 | 0 | 0 | 0 | 0 |
| GP02 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP03 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP04 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP05 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP06 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP07 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP08 | 0 | 0 | 306.1665 | 306.3928 | 305.7953 | 303.873 |
| GP09 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP10 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP11 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP12 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP13 | 178.5871 | 177.5459 | 176.061 | 173.8676 | 170.5204 | 165.2348 |
| GP14 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP15 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP16 | 113.3539 | 102.2961 | 91.1301 | 80.9478 | 72.439 | 65.7656 |
| GP17 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP18 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP19 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP20 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP21 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP22 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP23 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP24 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP25 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP26 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP27 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP28 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP29 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP30 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP31 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP32 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA01 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA02 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA03 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA04 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA05 | 0 | 0 | 299.957 | 303.2985 | 306.7151 | 310.2451 |
| GA06 | 42.4491 | 53.4066 | 62.9087 | 71.1778 | 78.4422 | 84.8973 |
| GA07 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA08 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA09 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 4-20: Azimuth Angles Report**

```
-------------------------------------------------------------------------

#REPORT: Horizontal DOP


TIME         HDOP

00:00:00     2.3713
00:10:00     1.8676
00:20:00     2.2039
00:30:00     1.9358
00:40:00     1.8606
00:50:00     1.8076
01:00:00     1.8158
01:10:00     2.3355
01:20:00     2.8001
01:30:00     3.1640
01:40:00     1.4046
01:50:00     1.3391
02:00:00     1.7325
02:10:00     2.0167
02:20:00     1.9315
02:30:00     1.9736
02:40:00     2.6903
02:50:00     2.3167
03:00:00     1.7574
03:10:00     1.5711
03:20:00     1.2934
03:30:00     1.2999
03:40:00     1.3600
03:50:00     1.4519
04:00:00     1.8557
04:10:00     3.6247
04:20:00     3.8054
04:30:00     3.2470
04:40:00     2.7964
04:50:00     2.5645
05:00:00     1.9532
05:10:00     1.6386
05:20:00     1.3633
05:30:00     1.2586
05:40:00     2.4313
05:50:00     2.4760
06:00:00     2.2997
06:10:00     2.1807
06:20:00     3.1113
06:30:00     3.6977
06:40:00     3.5513
```

**Figure 4-21: HDOP Report**

#REPORT: Elevation Angles (degrees)

| p. 01/24 | 00:00:00 | 00:10:00 | 00:20:00 | 00:30:00 | 00:40:00 | 00:50:00 |
|---|---|---|---|---|---|---|
| GP01 | 54.291 | 51.6406 | 0 | 0 | 0 | 0 |
| GP02 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP03 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP04 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP05 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP06 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP07 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP08 | 0 | 0 | 55.0935 | 59.5817 | 64.1283 | 68.6909 |
| GP09 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP10 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP11 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP12 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP13 | 44.5053 | 49.437 | 54.3866 | 59.3118 | 64.1473 | 68.7823 |
| GP14 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP15 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP16 | 63.4245 | 64.2738 | 63.937 | 62.4763 | 60.0867 | 57.0081 |
| GP17 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP18 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP19 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP20 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP21 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP22 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP23 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP24 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP25 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP26 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP27 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP28 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP29 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP30 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP31 | 0 | 0 | 0 | 0 | 0 | 0 |
| GP32 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA01 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA02 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA03 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA04 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA05 | 0 | 0 | 53.3806 | 56.3656 | 59.4092 | 62.5134 |
| GA06 | 73.5422 | 71.8308 | 69.8199 | 67.5793 | 65.1602 | 62.5992 |
| GA07 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA08 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA09 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA10 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 4-22: Elevation Angle Report**

```
-----------------------------------------------------------------------

#REPORT: Visible Satellites


TIME        VISIBLE SATELLITES

00:00:00    GP01 GP13 GP16 GA06 GL02

00:10:00    GP01 GP13 GP16 GA06 GL02

00:20:00    GP08 GP13 GP16 GA05 GA06 GL02

00:30:00    GP08 GP13 GP16 GA05 GA06 GL11

00:40:00    GP08 GP13 GP16 GA05 GA06 GA12 GL02 GL11

00:50:00    GP08 GP13 GP16 GA05 GA06 GA12 GL02 GL11

01:00:00    GP08 GP13 GP16 GA05 GA06 GA12 GL02 GL11

01:10:00    GP08 GP13 GA05 GA06 GA12 GL02 GL11 GL14

01:20:00    GP08 GP13 GA05 GA12 GL02 GL11 GL14

01:30:00    GP08 GP13 GA05 GA12 GL02 GL11 GL14

01:40:00    GP06 GP08 GP13 GA05 GA12 GL02 GL05 GL11 GL14

01:50:00    GP06 GP08 GP13 GA05 GA12 GL02 GL05 GL11 GL14

02:00:00    GP06 GP08 GP13 GA05 GA12 GL02 GL05 GL14

02:10:00    GP06 GP08 GP13 GA05 GA12 GL05 GL14

02:20:00    GP06 GP08 GP13 GA05 GA11 GA12 GL05 GL14

02:30:00    GP06 GP08 GP13 GA05 GA11 GA12 GL05 GL09 GL14

02:40:00    GP06 GP08 GA04 GA05 GA11 GA12 GL05 GL09 GL14

02:50:00    GP06 GP08 GA04 GA05 GA11 GA12 GL05 GL09 GL14

03:00:00    GP06 GP08 GP09 GA04 GA05 GA11 GA12 GL05 GL09 GL14

03:10:00    GP06 GP08 GP09 GA04 GA05 GA11 GA12 GL05 GL09 GL14

03:20:00    GP06 GP09 GA04 GA05 GA11 GA12 GL05 GL08 GL09 GL14
```

**Figure 4-23: Visible Satellites Report**

# 5 Conclusion

This document presented the design of the Planning Tool Simulator (PTS) along with the user manual. The PTS is a simulator tool developed to support to mission planning and satellite availability analysis.