

White Paper: Visualyse Interplanetary

Abstract The aim of Visualyse Professional is to be able to model a wide range of radio systems as possible. Until recently, a restriction has been that all stations, both transmit and receive, are located either on the Earth's surface or in orbit around the Earth. With increasing interest in missions to the Moon, Mars and other celestial bodies in the Solar System, Transfinite have been working on how to model these deep space systems. This White Paper describes in overview the new product, Visualyse Interplanetary, that will allow modelling of missions to and around the Moon and other planetary bodies.

Introduction

This White Paper is aimed at users that are familiar with Visualyse Professional who wish to try Visualyse Interplanetary, a new software product from Transfinite able to model radio interference problems in space, beyond the satellite systems orbiting Earth.

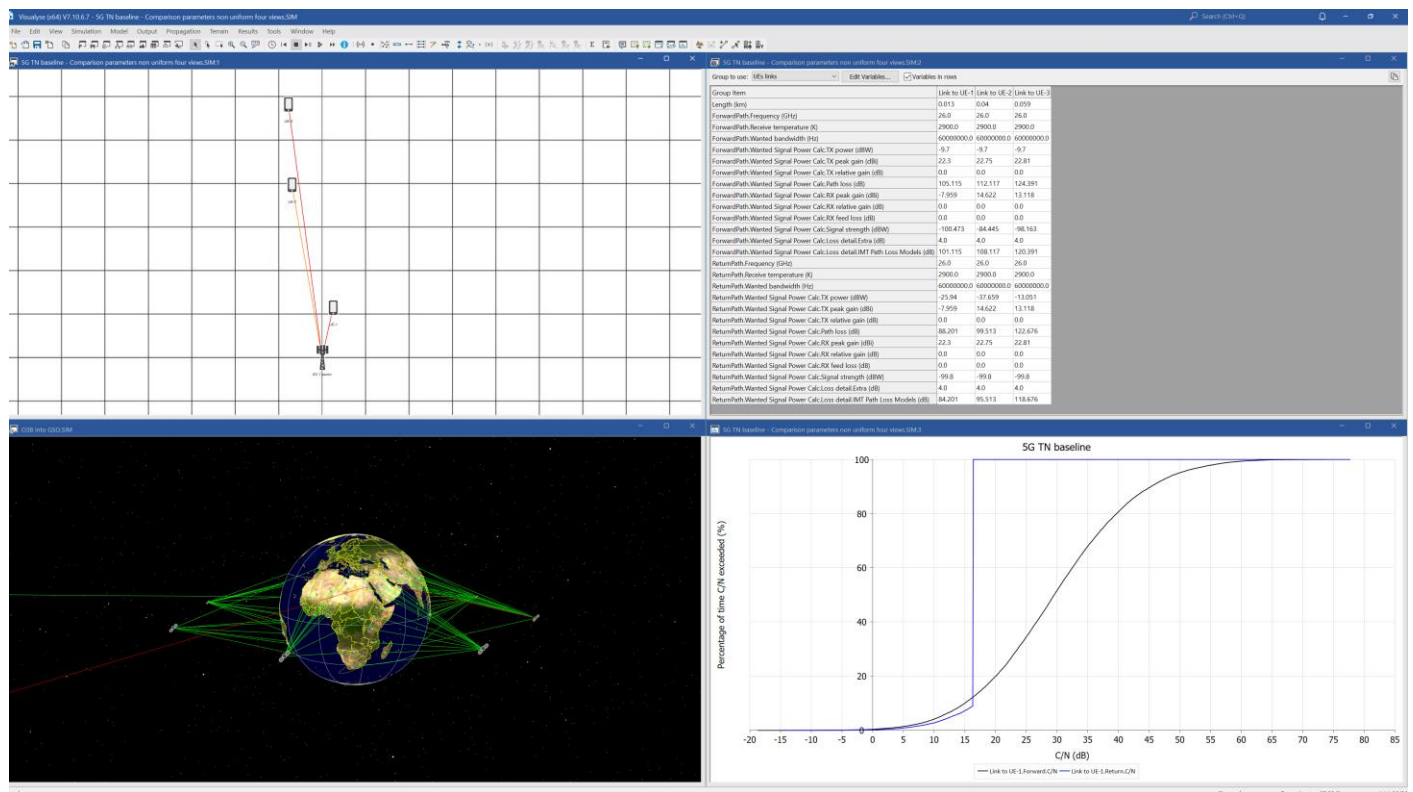
What is Visualyse Professional?

Visualyse Professional is a flexible study tool able to model a very wide range of radiocommunication systems, that can be used to analyse system performance including the impact of interference. Visualyse Professional is able to model transmit and receive stations located at fixed positions, mobile stations, aircraft, ships and also satellite systems including Earth stations, non-GSO satellites, HEO satellites and GSO satellites.

It can be configured to analyse spectrum sharing scenarios using a wide range of methodologies, including static, input parameter variation, area, dynamic, Monte Carlo and combinations such as area Monte Carlo.

Visualyse Professional includes a wide range of advanced features to enable it to analyse both co-frequency and non-co-frequency scenarios, the impact of terrain or clutter, the impact of traffic and complex handover strategies between satellites. These features allow it to model anything from a 5G network to a non-GSO mega-constellations such as SpaceX's Starlink or OneWeb.

An example screenshot of Visualyse Professional is shown below:



Visualyse Interplanetary

The objective of **Visualyse Interplanetary** is to extend the simulation ability of **Visualyse Professional** to allow:

1. Modelling of stations around other celestial bodies including the Moon and Mars
2. Enhance the geometric framework with a more detailed description of the Earth's shape and rotation characteristics.

The update to the geometric layer of **Visualyse** was an opportunity to include additional features, in particular:

- Modelling how the frequency at the receiver is altered due to Doppler shift
- tools support sun-synchronous orbit satellites
- a constellation collision prediction tool
- inclusion of the full TLE orbit prediction model.

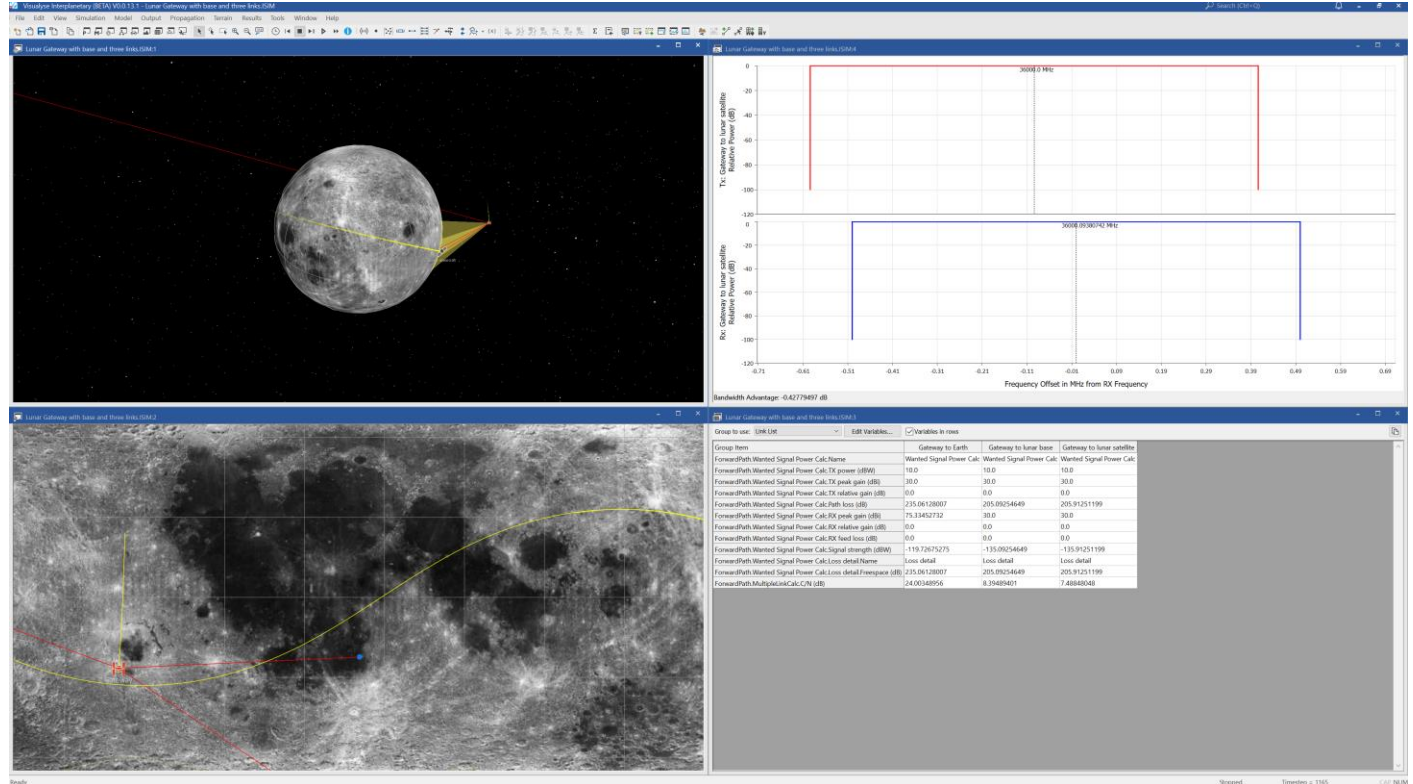
These enhancements allow a wide range of new scenarios to be modelled, such as:

- Checking there'd be no issues with harmful interference from crewed missions to the Moon or Mars using 4G and 5G mobile systems
- Checking that missions to the Moon or Mars from one space agency would not cause harmful interference into those of another
- Using more detailed orbit models to predict satellite positions and antenna pointing angles during the satellite or Earth station coordination process.

Installation and Configuration

The installation program should create a new directory and icon for the new version of **Visualyse**.

Visualyse Interplanetary uses a new set of overlays, which should be located in the relevant overlays directory. Note these overlays have an additional field in each of the XML files which defines the relevant celestial body. An example of the overlays is shown below:



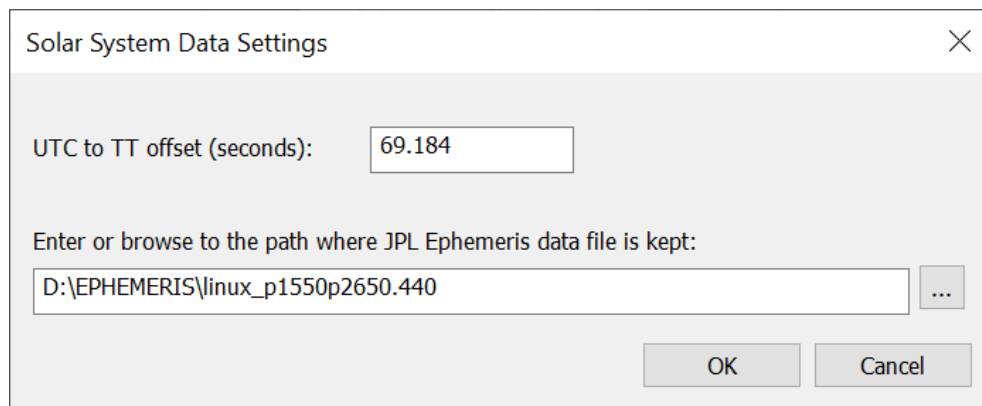
It is also necessary to have access to one of the JPL ephemeris data files. This file is called something like:

[Inxm13000p17000.431](#)

This can be downloaded from here:

<ftp://ssd.jpl.nasa.gov/pub/eph/planets/Linux/>

The first time that [Visualyse Interplanetary](#) is run it should be configured to point to this file using the menu option File|Solar System Settings. This will open the following dialog:



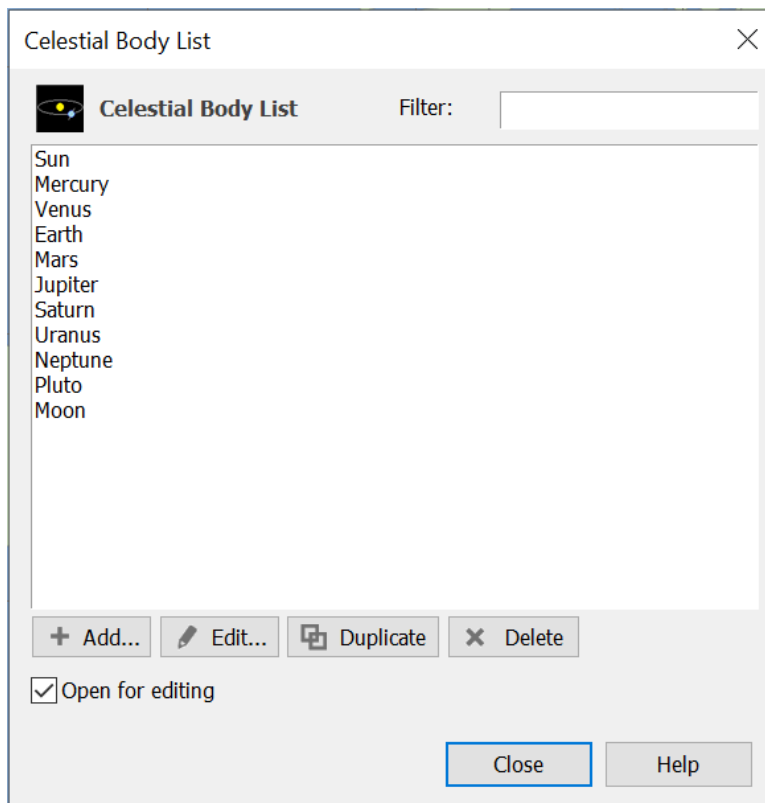
The dialog box is titled "Solar System Data Settings". It contains a label "UTC to TT offset (seconds):" followed by a text input field containing "69.184". Below this is a label "Enter or browse to the path where JPL Ephemeris data file is kept:" followed by a text input field containing "D:\EPHEMERIS\linux_p1550p2650.440" and a browse button "...". At the bottom right are "OK" and "Cancel" buttons.

The UTC to Terrestrial Time (TT) offset allows the dynamic time to be defined relative to UTC.

Solar System Objects

This version includes an additional list of objects to define the Solar System. This can be found under menu option Model|Solar System. If the JPL ephemeris file is not specified, then [Visualyse Interplanetary](#) will work in legacy mode. In this case, the list will only contain the standard [Visualyse Professional](#) Earth which is a sphere of radius $R_e = 6378.145$ km.

If the JPL ephemeris file is specified, then this will show the list of available celestial bodies:



The dialog box is titled "Celestial Body List". It features a "Filter:" text input field at the top right. Below the filter is a list of celestial bodies: Sun, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, and Moon. At the bottom, there are four buttons: "+ Add...", "Edit..." (with a pencil icon), "Duplicate" (with a copy icon), and "Delete" (with an 'x' icon). Below these buttons is a checked checkbox labeled "Open for editing". At the bottom right are "Close" and "Help" buttons.

You can add, edit, duplicate and delete celestial bodies, allowing moons of the major planets and asteroids to be entered. In the future, this could be extended to include the ability to import additional celestial bodies using a text file format (e.g. using orbit elements or J2000.0 state vectors). Each object can be viewed or edited using a dialog similar to this:

Edit Celestial Body

Name: Epoch...

Orbits: Orbit...

GM (km/s²): Polar axis right ascension (deg):

J2: Polar axis declination (deg):

Ellipsoid a (km): W at epoch (deg):

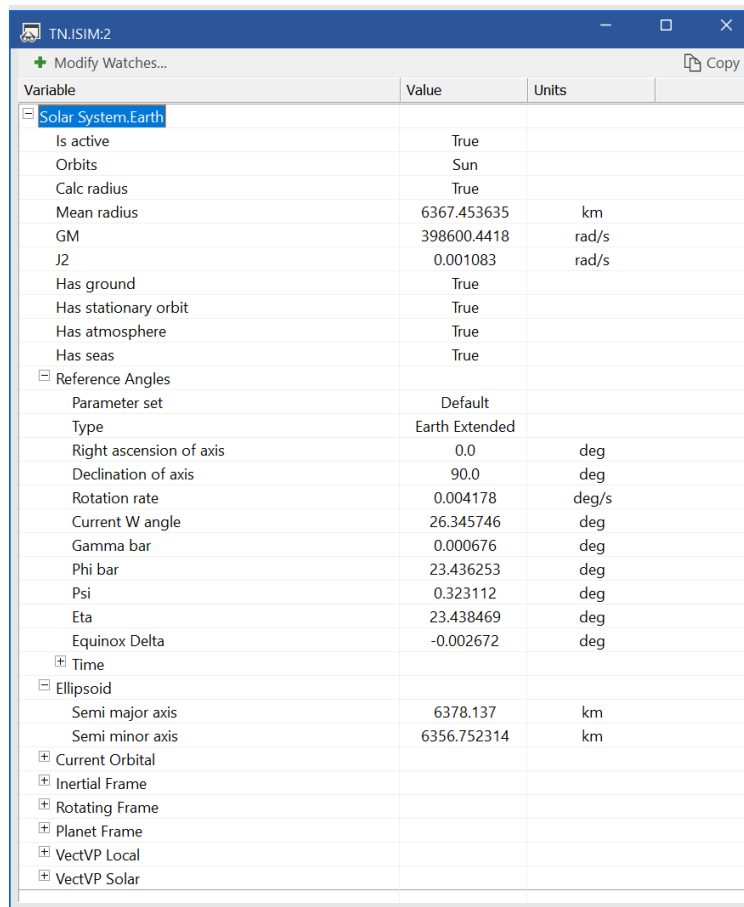
Ellipsoid b (km): Rotation rate (deg/s):

Calculate mean radius: ☒ Has ground: ☒

Mean radius (km): Has atmosphere: ☒

Has seas: ☒

The watch window can also be used to view the configuration parameters and also calculated parameters:



Variable	Value	Units
Solar System Earth		
Is active	True	
Orbits	Sun	
Calc radius	True	
Mean radius	6367.453635	km
GM	398600.4418	rad/s
J2	0.001083	rad/s
Has ground	True	
Has stationary orbit	True	
Has atmosphere	True	
Has seas	True	
Reference Angles		
Parameter set	Default	
Type	Earth Extended	
Right ascension of axis	0.0	deg
Declination of axis	90.0	deg
Rotation rate	0.004178	deg/s
Current W angle	26.345746	deg
Gamma bar	0.000676	deg
Phi bar	23.436253	deg
Psi	0.323112	deg
Eta	23.438469	deg
Equinox Delta	-0.002672	deg
Time		
Ellipsoid		
Semi major axis	6378.137	km
Semi minor axis	6356.752314	km
Current Orbital		
Inertial Frame		
Rotating Frame		
Planet Frame		
VectVP Local		
VectVP Solar		

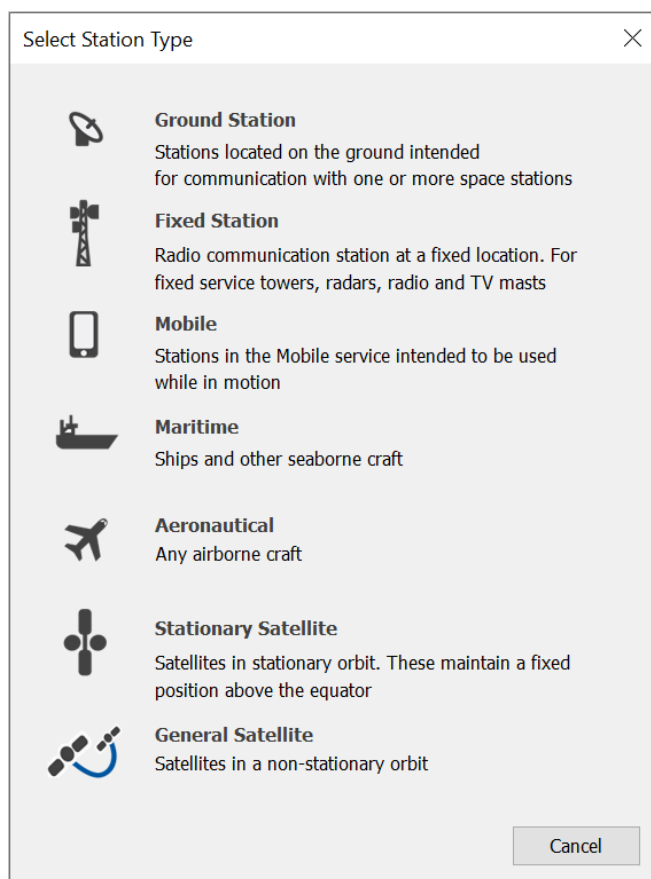
The Earth model in [Visualyse Interplanetary](#) is the standard WGS84 ellipsoid and that each object has defined what object it orbits. Each celestial object has flags to identify if it has {Ground, Atmosphere, Seas}. This field is used to identify what types of station are permitted – so, for example, aircraft would not be permitted on the Moon.

File Save and Load

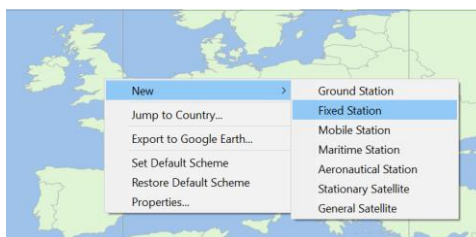
It is possible to save and load [Visualyse Interplanetary](#) simulations and load existing [Visualyse Professional](#) version 7.x files. It is not possible to save [Visualyse Interplanetary](#) simulations to [Visualyse Professional](#) file format.

Station Types

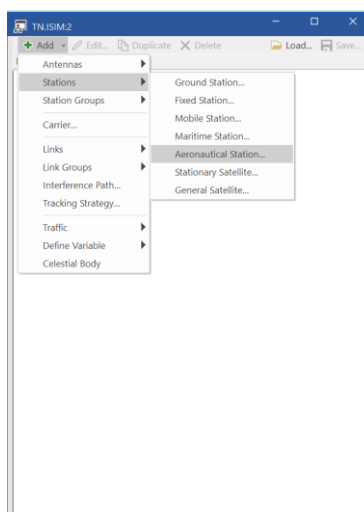
Station types have been relabelled to make them more generic and not Earth specific, as can be seen from the following dialog:



This is also visible in other places, such as right clicking on the map view:



And also in the model view:



Station Dialog

Each station dialog's position page has an additional field to specify which celestial body this station is defined relative to. Here it is possible to select a new celestial body:

The screenshot shows the 'Ground Station' dialog box with the 'Position' tab selected. The 'Celestial Body' dropdown menu is open, displaying a list of celestial bodies. The 'Earth' option is currently selected and highlighted. The 'Latitude' field is set to 0.0 degrees, 'Longitude' is 0.0 degrees, and 'Altitude' is 10.0 meters. The 'OK', 'Cancel', and 'Apply' buttons are visible at the bottom of the dialog.

Note there are checks that the celestial body and station type are compatible. For example, selecting Jupiter here will result in the following error:

The screenshot shows the 'Visualyse Interplanetary Problem' dialog box. It contains the following text:

Problem:
Invalid Celestial Body for this Station type

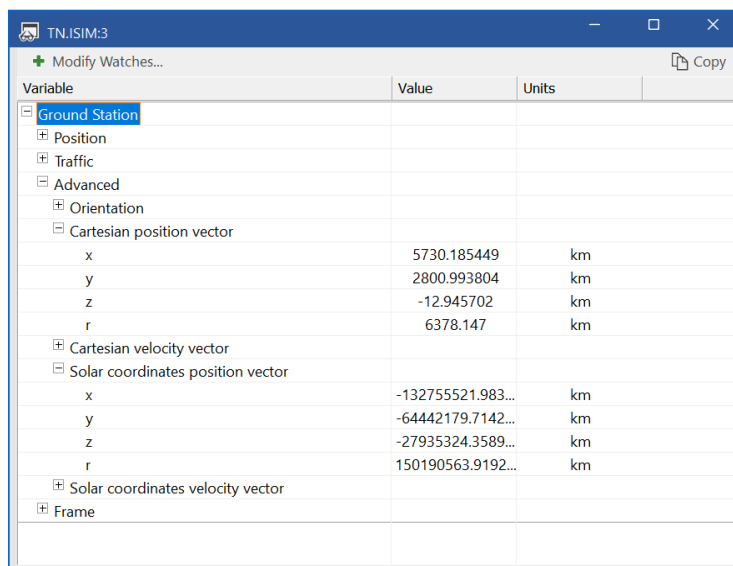
Explanation:
The Celestial Body must be valid for the given Station type. For example, The RB of a Ground, Fixed or Mobile station must have ground, while the RB of a Maritime Station must have seas and the RB of an Air Station must have an atmosphere

Suggestion:
Select a different Celestial Body

Buttons: Close, Help

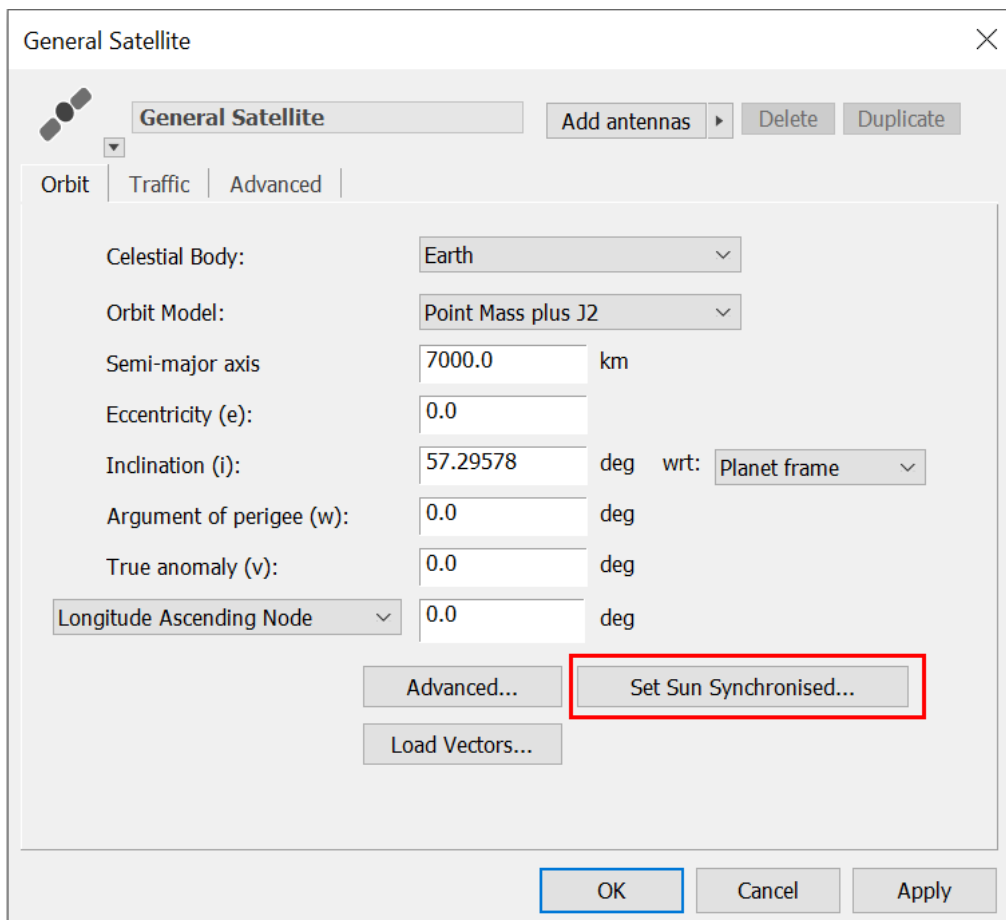
The location of each station is converted into position and velocity vectors relative to the selected celestial body. These are then converted into a common J2000.0 coordinate system which is sun centred using the mean equatorial plane.

These vectors are visible in the watch window:



Variable	Value	Units
Ground Station		
Position		
Traffic		
Advanced		
Orientation		
Cartesian position vector		
x	5730.185449	km
y	2800.993804	km
z	-12.945702	km
r	6378.147	km
Cartesian velocity vector		
Solar coordinates position vector		
x	-132755521.983...	km
y	-64442179.7142...	km
z	-27935324.3589...	km
r	150190563.9192...	km
Solar coordinates velocity vector		
Frame		

Satellite position and velocity vectors can be loaded via a CSV file to allow more advanced orbit types to be modelled including interplanetary transfer and halo orbits. The general satellite dialog (below) also allows the reference frame for the equator to be defined and includes a tool to create Sun synchronised orbits:



General Satellite

General Satellite | Add antennas | Delete | Duplicate

Orbit | Traffic | Advanced

Celestial Body: Earth

Orbit Model: Point Mass plus J2

Semi-major axis: 7000.0 km

Eccentricity (e): 0.0

Inclination (i): 57.29578 deg wrt: Planet frame

Argument of perigee (w): 0.0 deg

True anomaly (v): 0.0 deg

Longitude Ascending Node: 0.0 deg

Advanced... | **Set Sun Synchronised...** | Load Vectors...

OK | Cancel | Apply

The figure below shows the Sun synchronous tool dialog:

Set Sun Synchronised

Repeating track: ☒

Number of orbits: Valid

Days for these orbits: Valid

Semi-major axis: km

Inclination: deg

Longitude of ascending node: deg

Date and time satellite at equator for this longitude:

Date:

Time:

Set Orbit to This

Close

Station Wizards

These are celestial body aware: in most cases this is set via the template station (or, where available, an existing station). The preview window updates to reflect the celestial body in question e.g. default colour and whether to show country borders.

Note that when the Constellation Wizard uses an imported TLE file it is only applicable for Earth. The TLE import also uses the full SGP4 / SDP4 orbit prediction code.

Import Tools

The following approaches have been used when updating the import tools:

- SRS import: has to be Earth
- Terrestrial import: has to be Earth
- Import non-GSO: select via the satellite properties
- FS import: has to be Earth
- TX import: additional field to define celestial body
- RX import: additional field to define celestial body.

Propagation Models and Terrain Data

Most propagation models are only applicable for either terrestrial paths or Earth to space paths. The exception is free space path loss and the Extra Models (fixed loss and fixed loss / km) which are applicable for all paths. Earth to space paths that go from Earth to another planetary body e.g. Mars would only use those models at the Earth end of the link.

Terrain data and path profiles only work on terrestrial paths on Earth.

Doppler Shift

Features allow Doppler shift to be activated and included in the simulation:

The image shows a 'Simulation Settings' dialog box. The 'Name and Description' section has a 'Name' field with 'c:\temp\tn.isim' and a 'Description' field with 'Radio Interference Simulation'. Below this, it says 'ISIM file last saved with Visualyse Interplanetary version:0.0.14.2'. The 'Doppler effect' section is highlighted with a red box and contains the option 'Include Doppler shift:' with a checked checkbox. The 'Randomisation' section contains a text block explaining random number seeds and a 'Random number seed =' field with the value '12345678'. At the bottom are 'OK' and 'Cancel' buttons.

There are additional fields visible in the watch window that show how the various frequencies involved available in the Link Transmitter and Receiver objects:

The image shows a 'Simple doppler.ISIM:4' watch window. It has a 'Modify Watches...' button and a 'Copy' button. The table below lists the variables and their values.

Variable	Value	Units
TTC DL.(start-end).Transmitter		
Station	General Satellite	
Power Type	Fixed power level	
Transmit Power	-10.0	dBW
Wanted transmit frequency	2.1	GHz
TTC DL.(start-end).Receiver		
Station	Ground Station	
Noise Figure	3.0103	dB
Calculate Rain Noise	False	
System Noise Temperature	300.0	K
Wanted receive frequency	2.1000473	GHz
Wanted listen frequency	2.1	GHz
Wanted bandwidth adjustment	-3000.0	dB

There can be large differences in frequency if Stations are moving relative to each other. Hence many systems adjust their transmit or receive frequencies to automatically adjust. In [Visualyse Interplanetary](#), this can be modelled by using one of the following two options:

Fixed Link

TTC DL Propagation: Space<-->Earth

Start End Start->End End->Start Traffic Advanced

☒ enable link from Start to End station

Carrier: TT&C = 10.0 kHz

Frequency: Doppler adjust at Tx 2.1 GHz

Include wanted NFD ☐

Transmitter

Power at antenna: Fixed power level

Power: -10.0 dBW

Receiver

Feeder Receiver

System Noise: 300.0 K

☐ Calculate system noise

☐ Add rain noise from P.530/P.618

OK Cancel Apply

Fixed Link

TTC DL Propagation: Space<-->Earth

Start End Start->End End->Start Traffic Advanced

☒ enable link from Start to End station

Carrier: TT&C = 10.0 kHz

Frequency: Doppler adjust at Rx 2.1 GHz

Include wanted NFD ☐

Transmitter

Power at antenna: Fixed power level

Power: -10.0 dBW

Receiver

Feeder Receiver

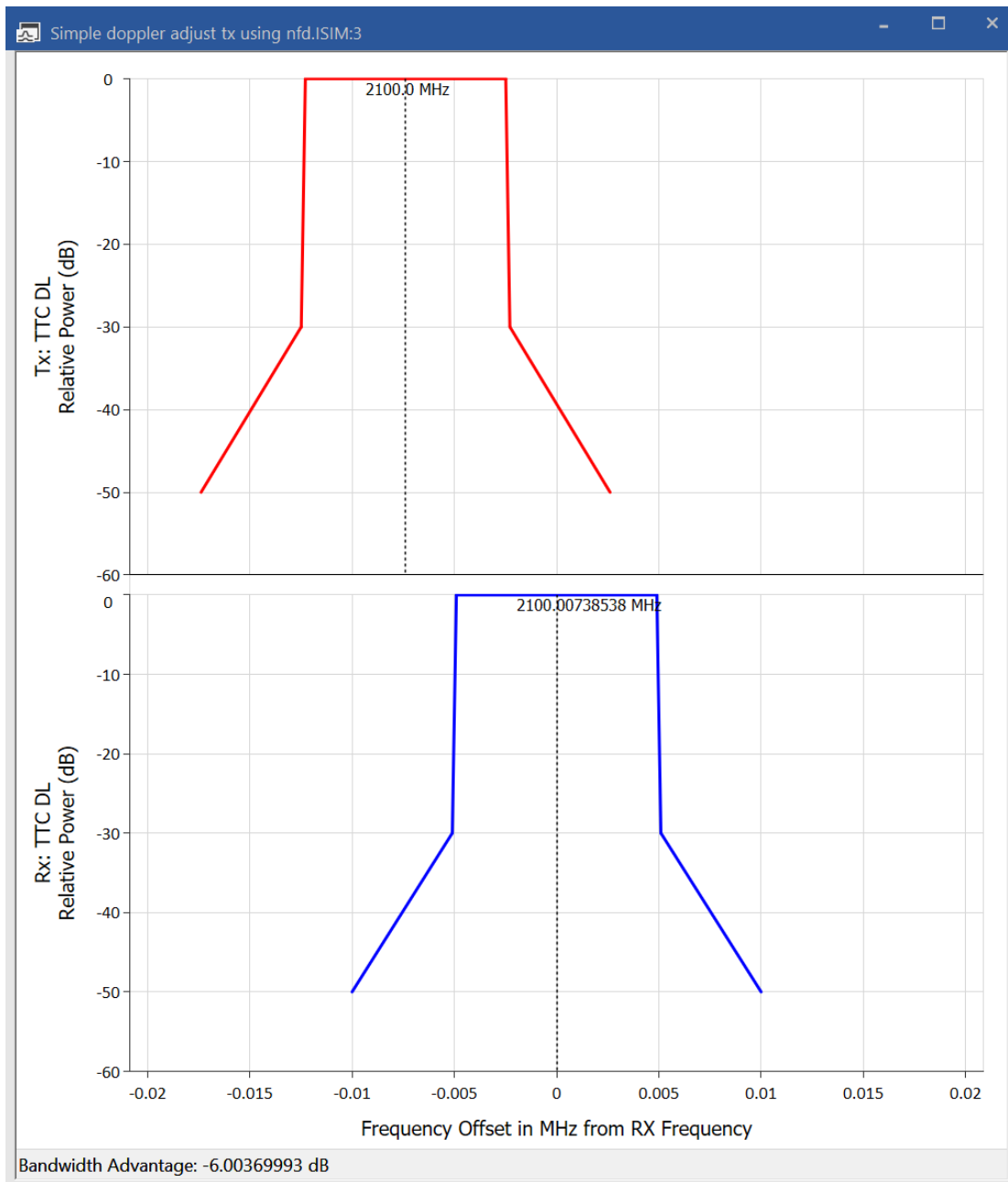
System Noise: 300.0 K

☐ Calculate system noise

☐ Add rain noise from P.530/P.618

OK Cancel Apply

In cases where there is no adjustment of the transmit or receiver frequency, there can be reduction in the wanted receive signal. This can be modelled using the net filter discrimination (NFD) of the wanted transmit spectrum mask and receiver filter, such as in this example:

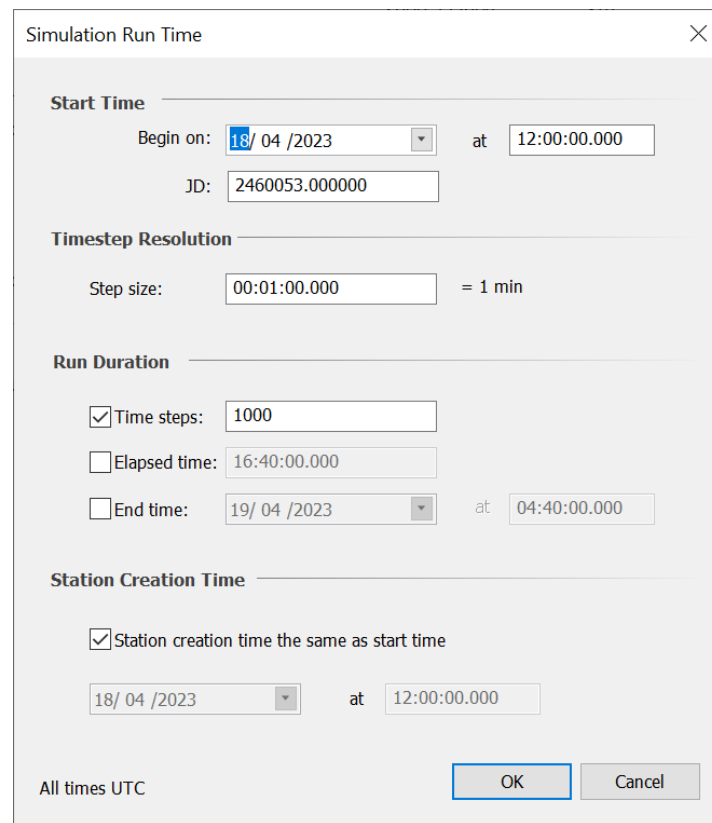


Time Dialog

There have been minor changes to the time dialog:

1. It is emphasized that all times are UTC
2. There is an option to define the start time as a Julian date
3. An option has been added to default the station creation time to be the start time.

The new dialog is shown below.



Simulation Run Time

Start Time

Begin on: 18/ 04 /2023 at 12:00:00.000

JD: 2460053.000000

Timestep Resolution

Step size: 00:01:00.000 = 1 min

Run Duration

☒ Time steps: 1000

☐ Elapsed time: 16:40:00.000

☐ End time: 19/ 04 /2023 at 04:40:00.000

Station Creation Time

☒ Station creation time the same as start time

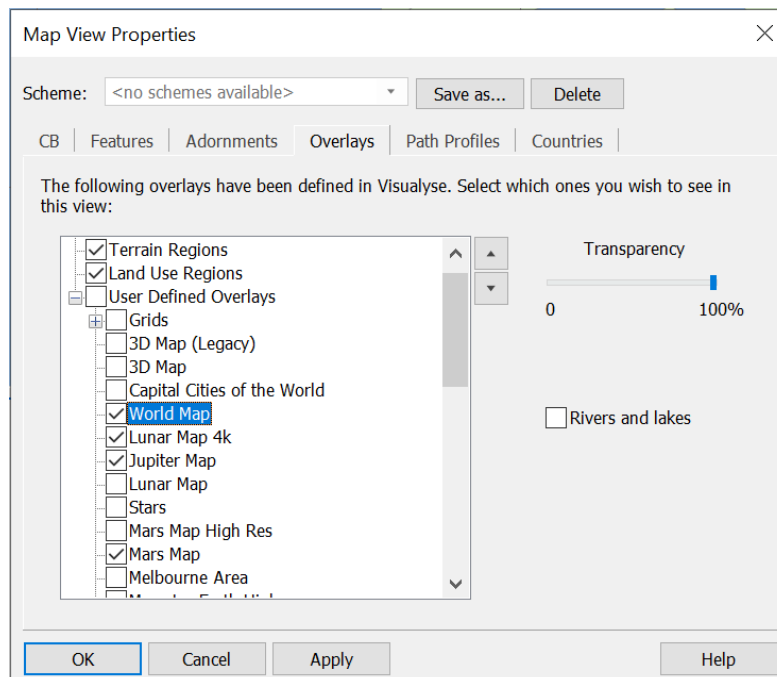
18/ 04 /2023 at 12:00:00.000

All times UTC

OK Cancel

Map and 3D View

These have an additional tab to define parameters related to the celestial body. Each of the overlays is checked to ensure it is compatible with the selected celestial body. Hence it is possible to specify these for multiple celestial bodies, but only the one(s) for the selected celestial body will be shown. This makes it easier to switch celestial body in the view without changing overlays:



Map View Properties

Scheme: <no schemes available> Save as... Delete

CB | Features | Adornments | **Overlays** | Path Profiles | Countries

The following overlays have been defined in Visualyse. Select which ones you wish to see in this view:

- ☒ Terrain Regions
- ☒ Land Use Regions
- ☐ User Defined Overlays
 - ☐ Grids
 - ☐ 3D Map (Legacy)
 - ☐ 3D Map
 - ☐ Capital Cities of the World
 - ☒ World Map
 - ☒ Lunar Map 4k
 - ☒ Jupiter Map
 - ☐ Lunar Map
 - ☐ Stars
 - ☐ Mars Map High Res
 - ☒ Mars Map
 - ☐ Melbourne Area

Transparency: 0 100%

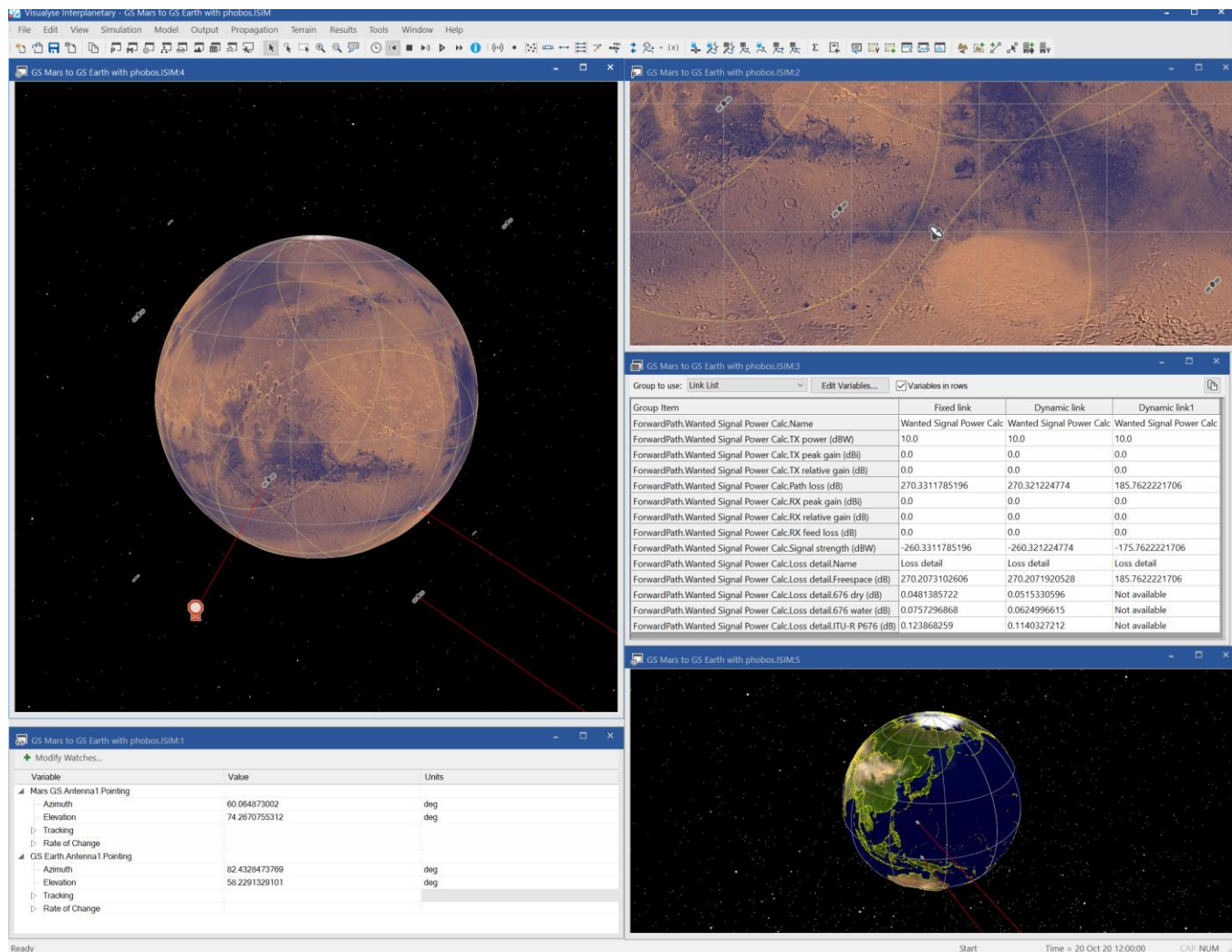
☐ Rivers and lakes

OK Cancel Apply Help

Countries etc. are only visible when the selected celestial body is Earth. The 3D viewpoint option is now defined as “fixed inertial viewpoint”. The 3D view also shows links to other celestial bodies.

Example Simulation

This simulation shows a ground station on Earth selecting a satellite from a constellation around Mars. The constellation around Mars is also communicating with a lander on the moon Phobos.



Libraries Used

Components from the following libraries are used by Visualyse Interplanetary:

Project Pluto:

<https://www.projectpluto.com/>

Standards of Fundamental Astronomy (SOFA):

<https://www.iausofa.org/>

Revisiting Spacetrack Report #3:

<https://www.celestrak.com/publications/AIAA/2006-6753/>

Further Development

Visualyse Interplanetary is intended to operate in parallel with Visualyse Professional as a separate install.

Further development of both products will take account of feedback from users. Please contact us for more information.

Email us at info@transfinite.com for further information or to give your views on this White Paper

About Transfinite

We are one of the leading consultancy and simulation software companies in the field of radiocommunications. We develop and market the leading **Visualyse** products:

- Visualyse Professional
- Visualyse Interplanetary
- Visualyse GSO
- Visualyse EPFD

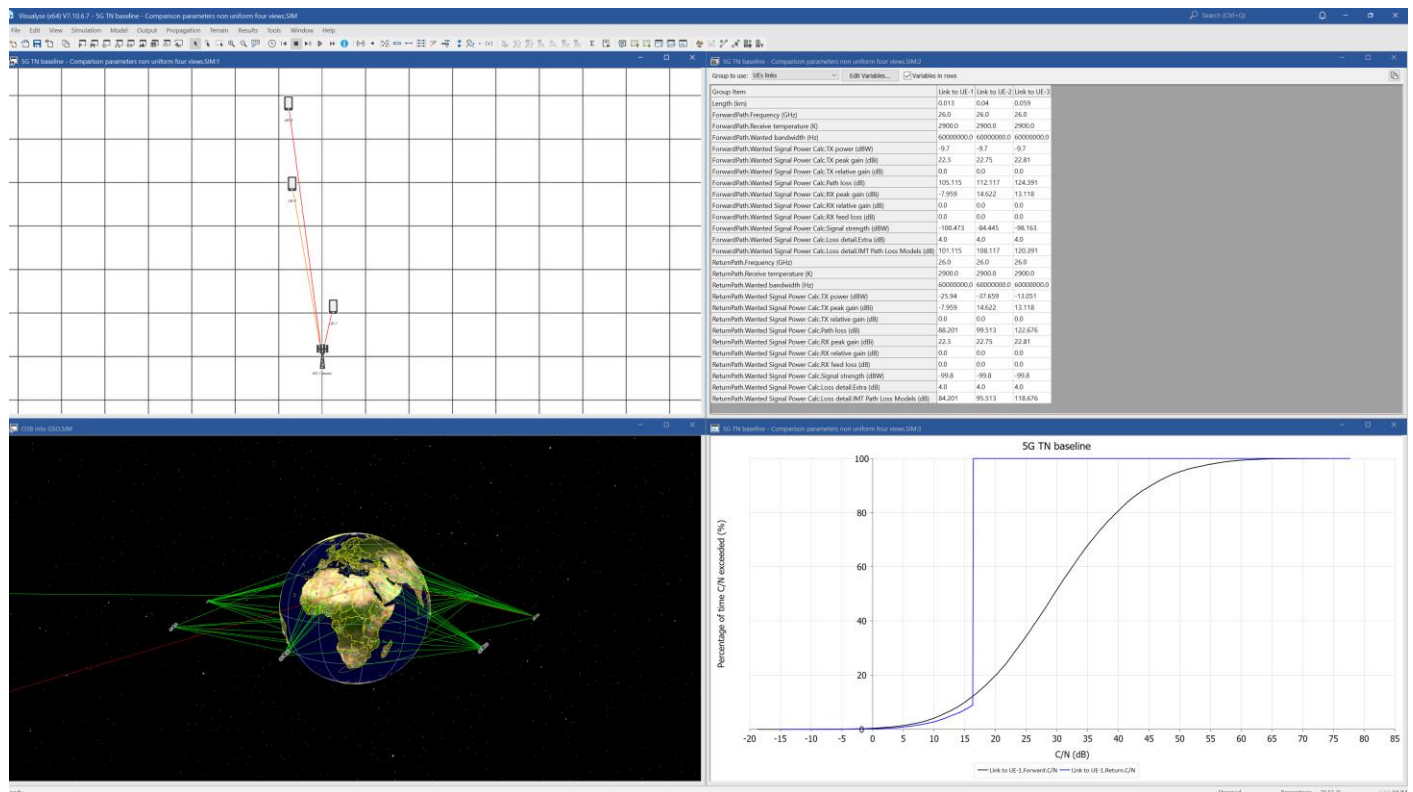
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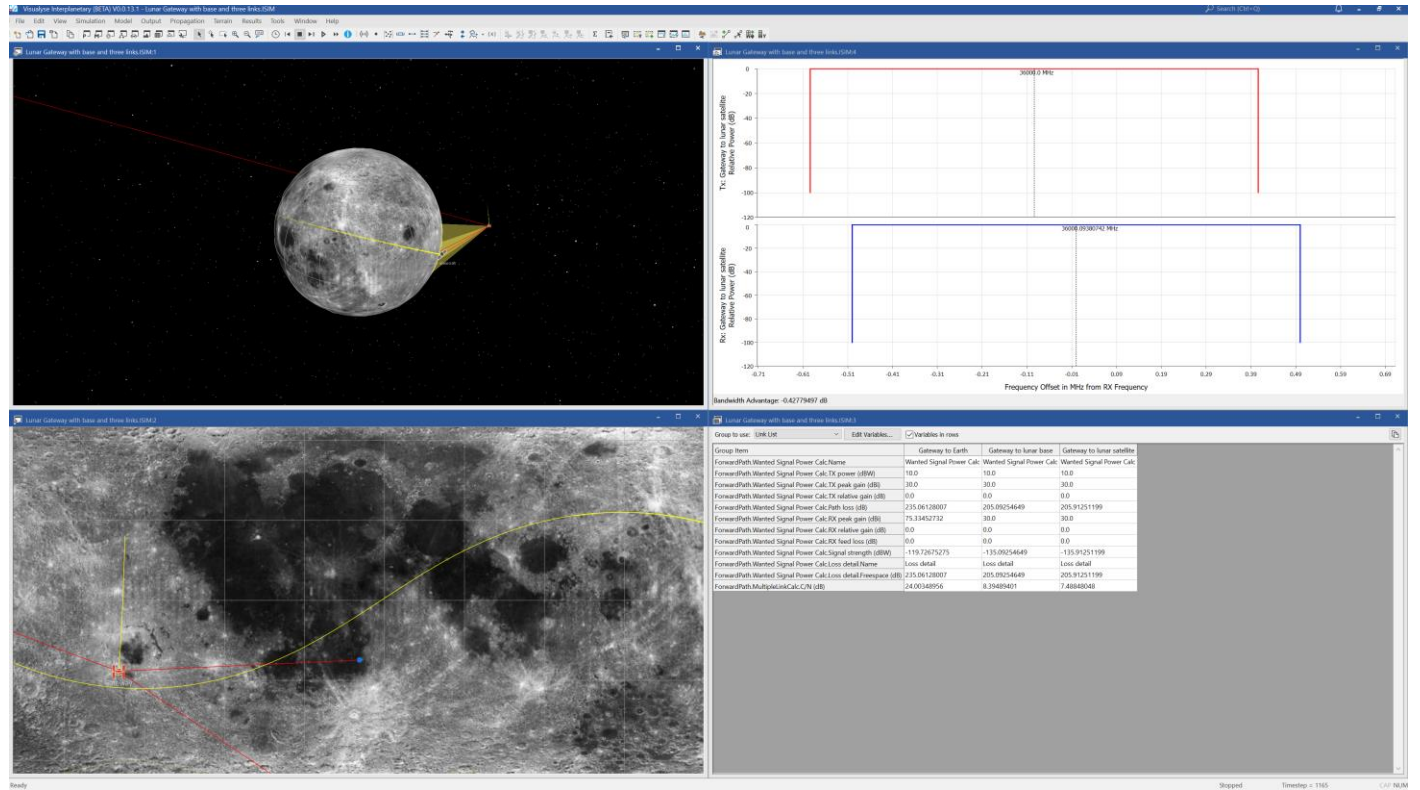


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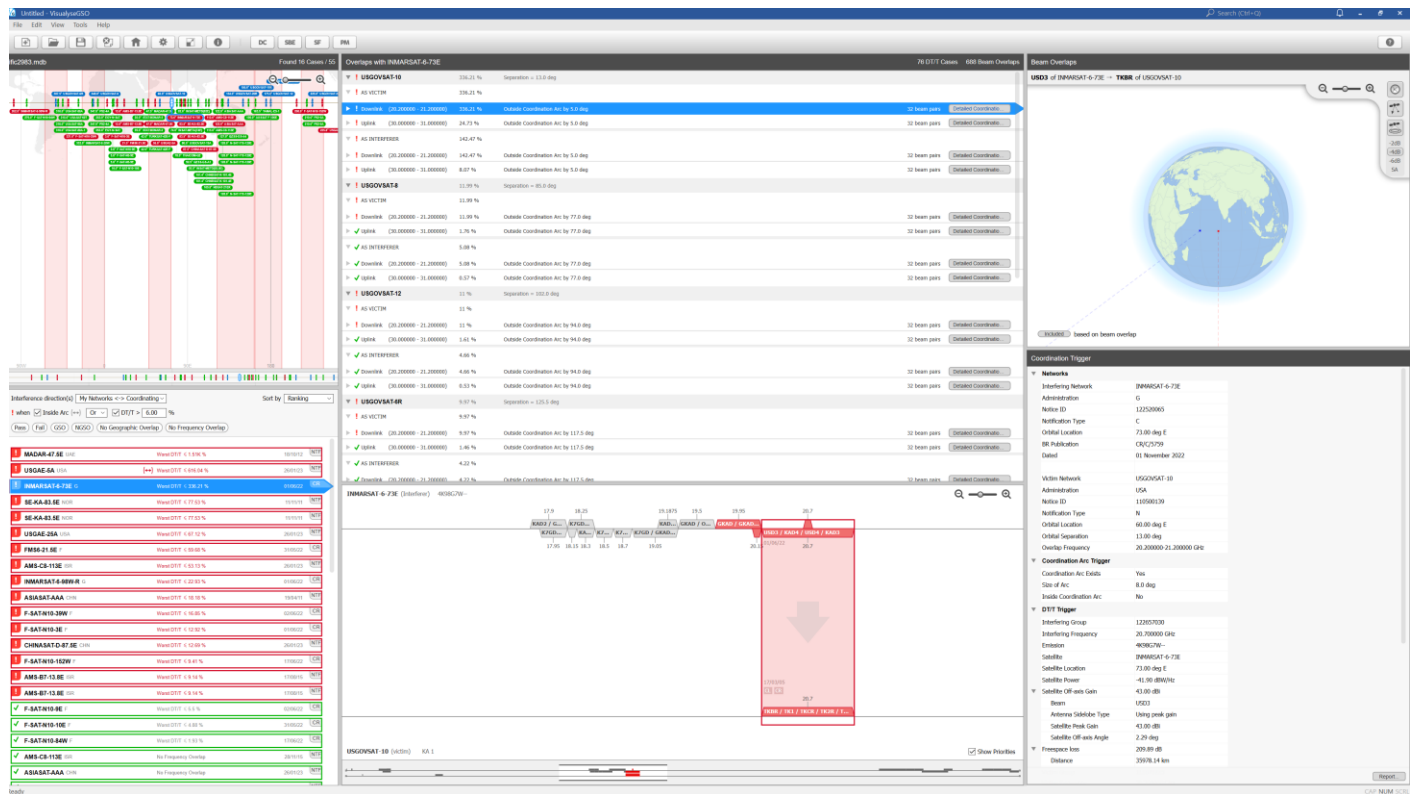
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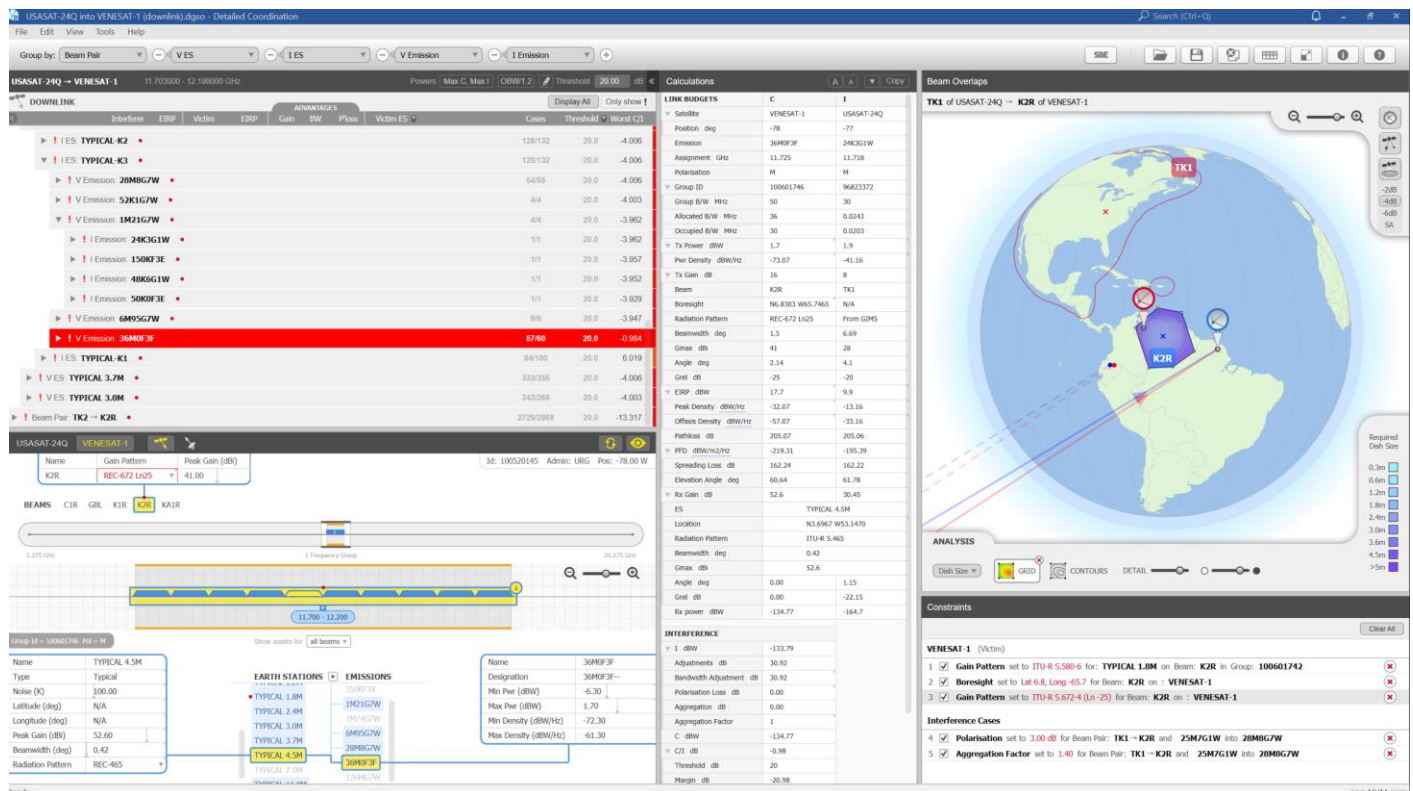


Visualyse GSO

We have developed [Visualyse GSO](#) to support satellite coordination tasks, in particular for GSO satellites. It includes IFIC checking, detailed C/I calculations and integrates with ITU databases such as the SRS/IFIC and GIMS. It can be also used to identify coordination requirements of non-GSO satellites.



The figure above shows the coordination trigger tool while the figure below shows the detailed coordination tool.



Email us at info@transfinite.com for further information or to give your views on this White Paper

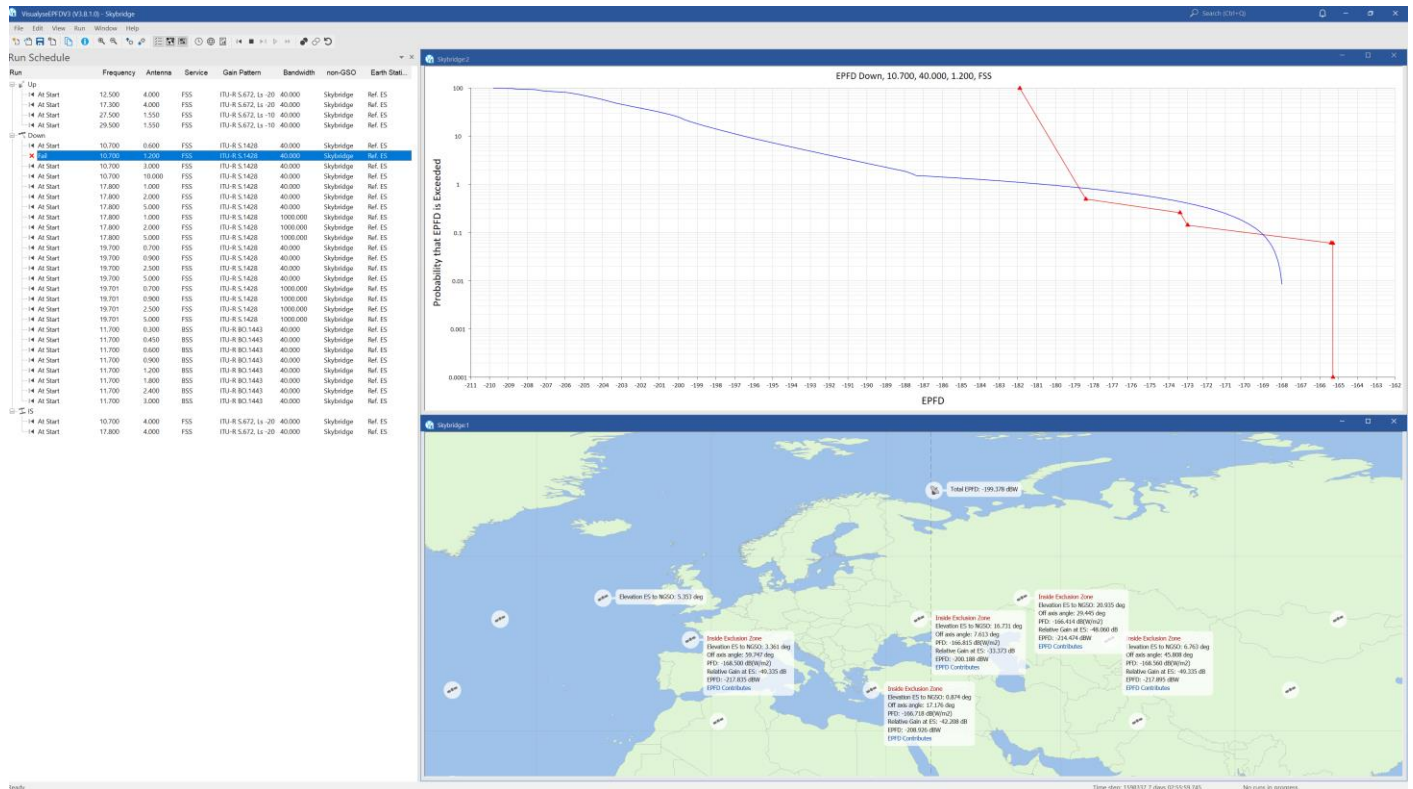
Visualyse EPFD

Our **Visualyse EPFD** software is the leading implementation of the algorithm in Rec. ITU-R S.1503. It has been verified during testing with the ITU BR and can calculate:

- EPFD (Up)
- EPFD (Down)
- EPFD (IS)

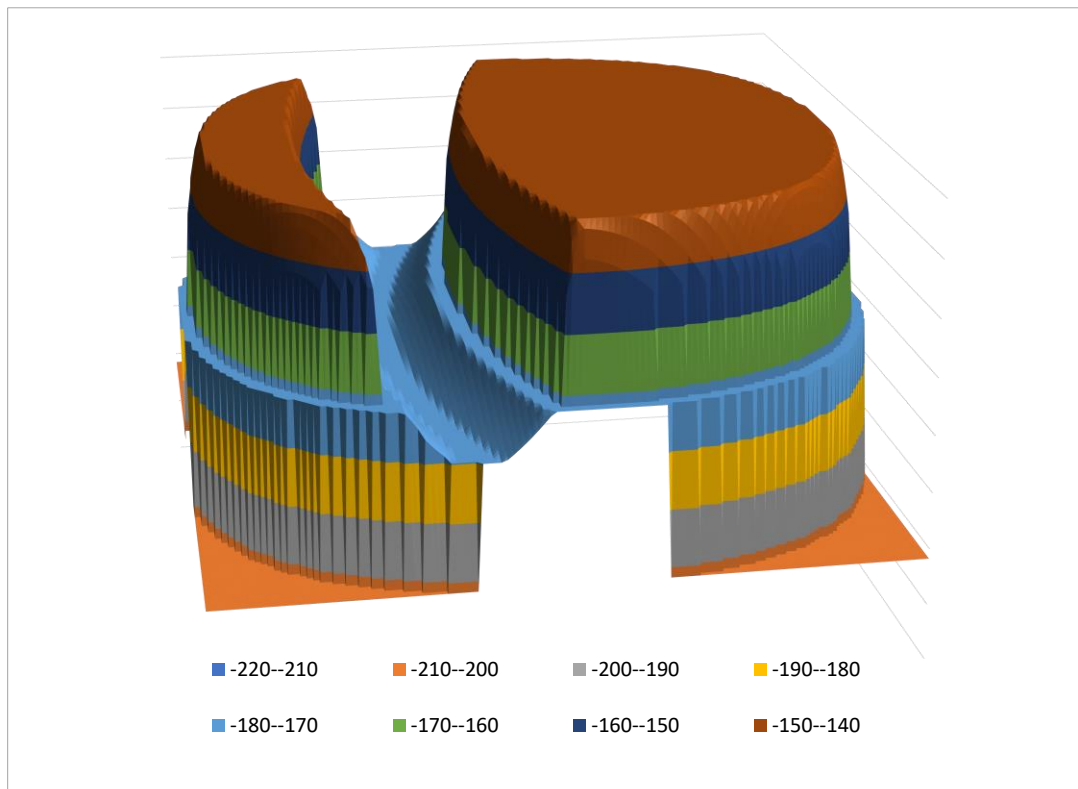
It can also analyse both the Article 22 and Articles 9.7A and 9.7B cases.

It is available in two versions, one the ITU's "black-box" for pass/fail decisions and the other a product with graphical user interface that provides feedback on the calculation process and allows additional options to be modified.



The **Visualyse EPFD** software is also capable of undertaking analysis using the methodology in Resolution 770 and includes methods being proposed for inclusion in a revision to Recommendation ITU-R S.1503, such as the Alpha Table Methodology.

An additional tool is available to assist in the generation of PFD masks:



Training Courses

We also provide training courses in the use of our products including advanced training that can cover modelling of specific systems and scenarios.

Consultancy Services

We can provide a wide range of consultancy services using our world-leading experts and software tools to rapidly generate solutions, including:

- Interference analysis and spectrum sharing studies
- Coordination support and meeting representation
- ITU-R and CEPT meeting representation and support
- Strategic consultancy to achieve regulatory goals.

Contact us

More information about these products and services is available at our web site:

<https://www.transfinite.com>

If you have any questions or comments about this Newsletter or would like more information, please do not hesitate to contact us at:

info@transfinite.com