Visualyse Interplanetary: General Satellite Dynamics Update and Lagrange Points

Abstract: Visualyse Interplanetary has recently been updated with improved general satellite dynamics definition and ability to specify spacecraft to be located at a Lagrange Points, as described in this Technical Note (TN).

General Satellite Dynamics

General satellite's dynamics can be selected by a number of methods, such as:

- Orbit model of point mass
- Orbit model of point mass plus J2
- Two-line element set using SGP4/SDP4
- Position and velocity vectors.

A new method is now available, namely:

• Selected as being located at a Lagrange point.

These are described further below.

Point Mass and Point Mass Plus J2 Orbit Models

General satellite station types are often defined using the standard Keplerian orbit elements, as shown below:

General Satellite			×
General Satellite	Ad	dd antennas 🕨 Delete Duplicate	Ð
Orbit Traffic Advanced			
Celestial Body:	Earth	~	
Orbit Model:	Point Mass	~	
Semi-major axis (a):	7000.0	km	
Eccentricity (e):	0.0		
Inclination (i):	57.29578	deg wrt: Planet frame \checkmark	
Argument of perigee (w):	0.0	deg	
True anomaly (v):	0.0	deg	
Longitude Ascending Node $$	0.0	deg	
A	Advanced	Set Sun Synchronised	
		OK Cancel Apply	y



2 | P a g e

There are also options to define the reference from the ascending node and equatorial plane.

For Earth orbiting stations where the orbit modal is Point Mass plus J2, it is also possible to use the tool to set the orbit to be sun-synchronised.

Two-line element set using SGP4/SDP4

Another way to define orbit elements is via the Two-Line Element (TLE) which looks a bit like this:

ISS (ZARYA) 1 25544U 98067A 24037.20615536 .00014912 00000+0 27301-3 0 9996 2 25544 51.6401 249.3892 0001810 205.4863 314.8810 15.49552210438086

These specify the measured dynamics of satellites actually orbiting the Earth.

If the TLE option is selected, the dialog changes to allow a TLE to be loaded from a text file, as shown here:

General Satellite	×
●●● ISS(ZARYA) ▼ Orbit Traffic Advanced	Add antennas Delete Duplicate
Celestial Body:	Earth 🗸
Orbit Model:	TLE using SGP4 SDP4
Element:	Load TLE ISS(ZARYA)
TLE line 1: 10 980674	A 24037.20615536 .00014912 00000+0 27301-3 0 99
TLE line 2: 4 51.6401	1 249.3892 0001810 205.4863 314.8810 15.4955221043
	OK Cancel Apply

The orbit model is then the SGP4/SDP4 from Space-Track.

Position and Velocity Vectors

Another method to define the station's location is directly via the spacecraft's position and velocity vectors at specific times, combined with Lagrangian interpolation.

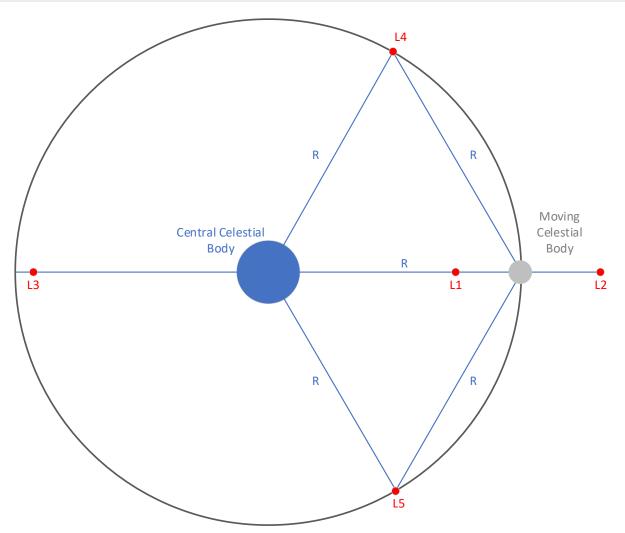
General Satellite		×
●●● ISS(ZARYA) ▼	Add antennas Delete Duplicate	
Orbit Traffic Advanced		1
Celestial Body:	Earth \checkmark	
Orbit Model:	Vectors ~	
Time step size (s):	180.0	
Reference frame:	32000.0	
Array size:	29750	
	Load Vectors	
	OK Cancel Apply	

This enables the position and velocity of the spacecraft to be specified in J2000.0 vectors centred on the specified celestial body. The format of the data is comma separated values (CSV), with example:

100					
2458857					
0.51458					
180					
0					
29750					
-2317.25	-990.679	2798.663	-1.49353	0.369327	-0.36886
-2582.61	-922.797	2728.248	-1.45465	0.384531	-0.41276
-2840.88	-852.38	2650.343	-1.415	0.397526	-0.45212

Specify Station at Lagrange Point

Lagrange points are locations within the gravitational influence of two celestial bodies where there is equilibrium. Spacecraft can be located at these points and remain stationary relative to the two celestial bodies. The locations are shown in the figure below:



Examples of Lagrange points include those within the Earth-Moon system and the Sun-Earth system.

In Visualyse Interplanetary, a General Satellites can be selected as being located at one of these points by identifying the moving celestial body and then the Lagrange point of interest. The central celestial body is then automatically identified as will be the one that the moving celestial body orbits around. So, for example:

- to locate a General Satellite in one of the Earth-Moon Lagrange points, select as celestial body the Moon.
- to locate a General Satellite in one of the Sun-Earth Lagrange points, select as celestial body the Earth.

An example is shown in the figure below:

General Satellite		×
JWST	Add antennas Delete Duplicate	
Orbit Traffic Advanced		
Celestial Body:	Earth V	
Orbit Model:	Lagrange point \checkmark	
Lagrange point:	L2 ~	
	OK Cancel Apply	

Note it is not possible to locate a Lagrange point when the celestial body is the Sun or Earth in ECI mode as there is no central celestial body in either case.

The Lagrange points are calculated using the approximation that the moving celestial body mass is significantly less than that of the central celestial body. More information is available in this reference:

http://physics.wku.edu/~gibson/astr414/lab/lagrange/L_calc_cornish.pdf

The Lagrange points are assumed to be in the plane of the moving celestial body's orbit around the central celestial body.

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

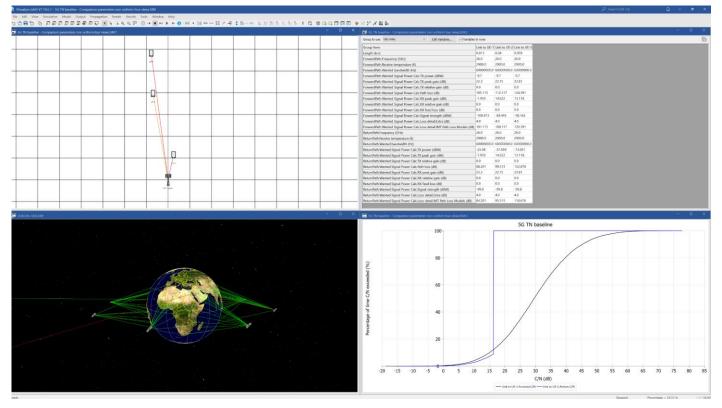
These are described further below.

Visualyse Professional

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

It can be configured to analyse spectrum sharing scenarios using a wide range of methodologies, including static, input parameter variation, area, dynamic, Monte Caro 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 nonco-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:



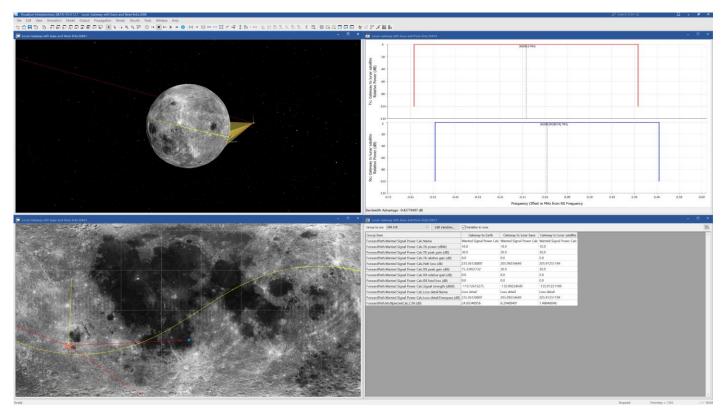
Visualyse Interplanetary

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.

An example screenshot of Visualyse Interplanetary is shown below:

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



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.

Untitled - VisualyseGSO File Edit. View Tools Help							₽ Search (Ctrl+Q)	Q - 0 ×
	PMA							0
		_						
flc2983.mdb Found 16 Cases / 56	· ·			76 DT/T	ases 688 Beam Overleps	Beam Overlaps		
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	V AS VICTIM	336.21 %						
		336.21 %	Dutilde Coordination Arc by S.D dep		Detailed Coordinatio	1		
	Uplink (30.000000 - 31.000000)	24.73 %	Dutside Coordination Arc by 5.0 deg	32 beam pairs	Detailed Coordinatio			
	V AS INTERFERER	142,47 %						-269
(17 AMAN) (17 AMAN) (17 AMAN) (17 AMAN) (17 AMAN) (17 AMAN)	Downlink (20.200000 - 21.200000)	142.47 %	Outside Coordination Arc by S.D deg	32 beam pairs	Detailed Coordinatio		A second	-268 -268 -268 -268
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	V 🗸 AS INTERFERER	4.65 %				Coordination Trigger		
<u>xiv</u> <u>xi</u> z <u>ta</u>	▷ ✓ Downink (20.200000 - 21.200000)	4.05.%	Dutade Coordination Arc by 14.0 deg	32 beam pars	Detailed Coordinate	T Networks		
	► ✓ Uplink (30.000000 - 31.000000)	0.53 %	Outside Coordination Arc by 94.0 deg	32 beam pairs	Detailed Coordinate	Interfering Network	INMARSAT-6-73E	
Interference direction(s) My Networks <> Coordinating <> Sort by Ranking <>	V USGOVSAT4R	9.92 %	Separation = 125.5 deg			Administration	6	
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SE-KA-83.5E NOR WestOTT CTT:53 N 101011			KAD2 / GKZGDKZGDKAD,KKAD / OGKAD / GKAD			Orbital Location	N 60.00 deg E	
UBCAE-25A USA Www.t0T/T 667.12 % 2601023			K7GD / KA / K7 / K7 / K7GD / GKAD / USD3 / KAD4 / KAD3 / KAD4 /			Orbital Separation	13.00 deg	
FMS6-21.5E r Went DT/T \$ 59:55 % 310522			17.05 18.15 18.3 18.5 18.7 19.05 20.3 ^{01/09/22} 28.7			Overlap Frequency	20.20000-21.20000 GHz	
AMS-CE-11SE ISR WestOTIT 453.13 % 260123						Coordination Arc Trigger Coordination Arc Prists		
INMARSAT4-00W-R G West DT/T 5 22:33 N 010622 CR						Size of Arc	Yes 8.0 deg	
ASIASAT-AAA CHN WeekDT/T \$18.18 % 19.5411						Inside Coordination Arc	No	
F-SAT-N10-J6W / Want DT/T 4 16.85 % 02/06/22						v DT/T Trigger		
F-SAT-N10-JE r WewlOTIT \$12:32 N 0100/22 CR						Interfering Group	122657030	
CHINASATD 87.5E CHN WateDTIT 5 12.09 % 2014/23 MTF						Interfering Frequency Emission	20.70000 GHz 4K96G7W	
F-SAT-N10-152W / WestOTT (S 41 S 170022 C						Satelike	INMARSAT-6-73E	
AMS-87-13.0E GR WestOTIT \$ 9.94 % \$70015						Satelite Location	73.00 deg E	
AMS-87-13.0E SR WestOTT (3.54 % 1700/15 (17783/05 (T)			Satelite Power Satelite Off-axis Gain	-41.90 dBW/Hz 43.00 dB	
			20.7			Beam	0503	
✓ F-SATN10-BE F Www.DT/T C55% 020622 C			TKBR / TKL / TKOR / TKBR / T			Antenna Sidelobe Type	Using peak gain	
✓ F-SAT-N10-10E F Weet DT/T C 4 88 % 316622 CR						Satelike Peak Gain Satelike Off-axis Angle	43.00 dB	
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leady to the second sec								CAP NUM SCRU

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 Technical Note

USASAT-24Q into VENESAT-1 (downlink).dgso -	Detailed Coordination								P Search (Ctrl+Q) Q	- 8
Edit View Tools Help										
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> 1 LES. TYPICAL-K2 .			128/132	20.0	-4.006	Position deg	-78 36M0F3F	-77 24K3G1W		-
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▶ VEmission 28M8G7W .			54/55		-4.006	Polarisation	м	м		
						* Group ID	100601746	96823372	1 72-22	
► ! V Emission 52K1G7W •			4/4	20.0	-4.003	Group B/W MHz	50	30		
VEmission: 1M21G7W •			- 414	20.0	-3.962	Allocated B/W MHz Occupied B/W MHz	36	0.0243		
▶ I Emission 24K3G1W •			1/1	20.0	-3.962	TX Power dBW	1.7	1.9		
I Emission: 150KF3E			- 1/1	20.0	-3.957	Pwr Density dBW/Hz	-73.07	-41.16		
▶ ! Emission. 48K6G1W .			1/1	20.0	-3.952	v Tx Gain dB	16	8		
► I Emission SOKOF3E •					-3.929	Beam	K2R	TKI		
						Boresight	N6.8303 W65.7465			
VEmission 6M95G7W •			9.9		-3.947	Radiation Pattern Beamwidth deg	REC-672 Ln25	From GIMS 6.69		
VEmission: 36M0F3F			57/60	20.0	-0.984	Gmax dti	41	28		
▶ TES TYPICAL-K1 .			64/100	20.0	6.019	Angle deg	2.14	4.1	K2R	
▶ 1 VES TYPICAL 3.7M .			333/365	20.0	-4.006	Grel d8	-25	-20		
VES TYPICAL 3.0M .			343/368	20.0	-4.003	v EIRP dBW	17.7	9.9		
Beam Pair TK2 → K2R ■			2729/2858	20.0	12.217	Peak Density dBW/Hz	-32.07	-13.16		
						Offaxis Density dBW/Hz Pathicss dB	-57.07	-33.16		
SASAT-24Q VENESAT-1						v PFD dBW/m2/Hz	-219.31	-195.39		
Name Gain Pattern Peak Ga	in (dBl)		Id: 100520145 Admin:	URG Pos: -	78.00 W	Spreading Loss dB	162.24	162.22		
K2R REC-672 Ln25 # 41.00						Elevation Angle deg	60.64	61.78		
BEAMS CIR GEL KIR KOR KAIR							52.6	30.45		
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tude (deg) N/A	TYPICAL 1.8M TYPICAL 2.4M	- 1M21G7W	Max Pwr (dBW)	1.70		Aggregation dB	0.00		3 Gain Pattern set to TTU-R 5.672-4 (Ln -25) for Beam: K2R on : VENESAT-1	
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ak Gain (dBi) 52.60	TYPICAL 3.7M	6M95G7W	Max Density (dBW/Hz)	-61.30	_	C dBW	-134.77		4 🗹 Polarisation set to 3.00 dB for Beam Pair: TK1→K2R and 25M7G1W into 28M8G7W	
anwidth (deg) 0.42	TYPICAL 4.5M	26M9G7W .				⇒ C/I d8	-0.98		5 🗹 Aggregation Factor set to 1.40 for Beam Pair: TK1→K2R and 25M7G1W into 28M8G7W	
diation Pattern REC-465 *	TYPICAL 2.6M	JONGEN I				Threshold dB	20			

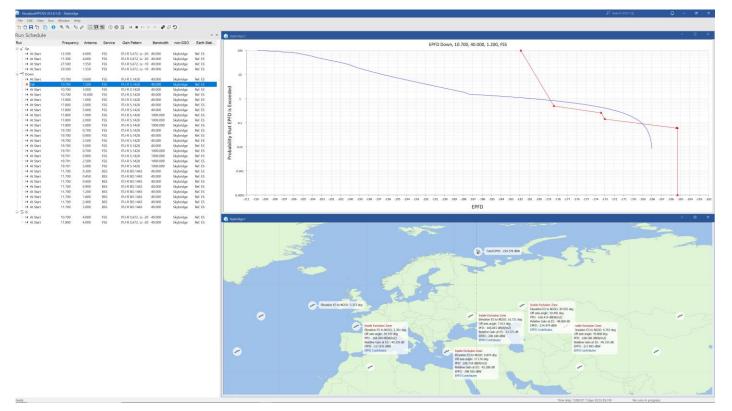
Visualyse EPFD

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:

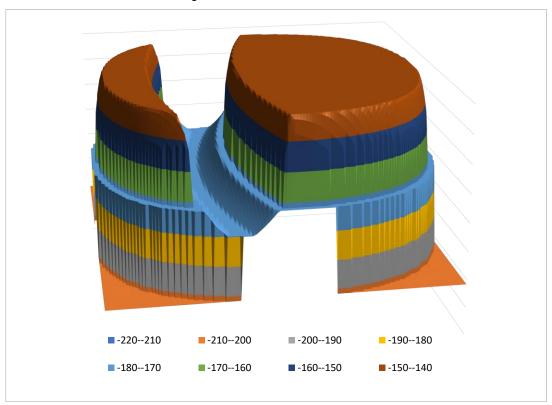
- EPFD (Up)
- EPFD (Down)
- EPFD (IS)

It can also analyse both the Article 22 and Articles 9.7A / 9.7B cases and also undertake Resolution 770 analysis using the algorithm in Recommendation ITU-R S.2157.

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.



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