

ITUEvents

ITU World Radiocommunication Seminar 2018

3-7 December 2018
Geneva, Switzerland

www.itu.int/go/ITU-R/WRS-18



Equivalent power
flux density limits
(EPFD)

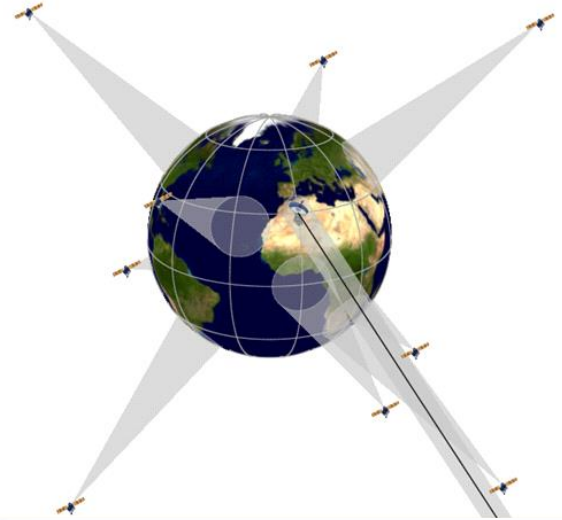
By SSC

ITU-R

ITU HQ Geneva,
6 December, 2018

EPFD

- **Equivalent power-flux density** (EPFD) takes into account the aggregate of the emissions from all non-GSO satellites in the direction of any GSO earth station, taking into account the GSO antenna directivity
- EPFD considers pointing of a victim receiving antenna with respect to any source of interference
- Complex calculation methodology considers an interference varying in time and space



S.1503-38

What is EPFD?

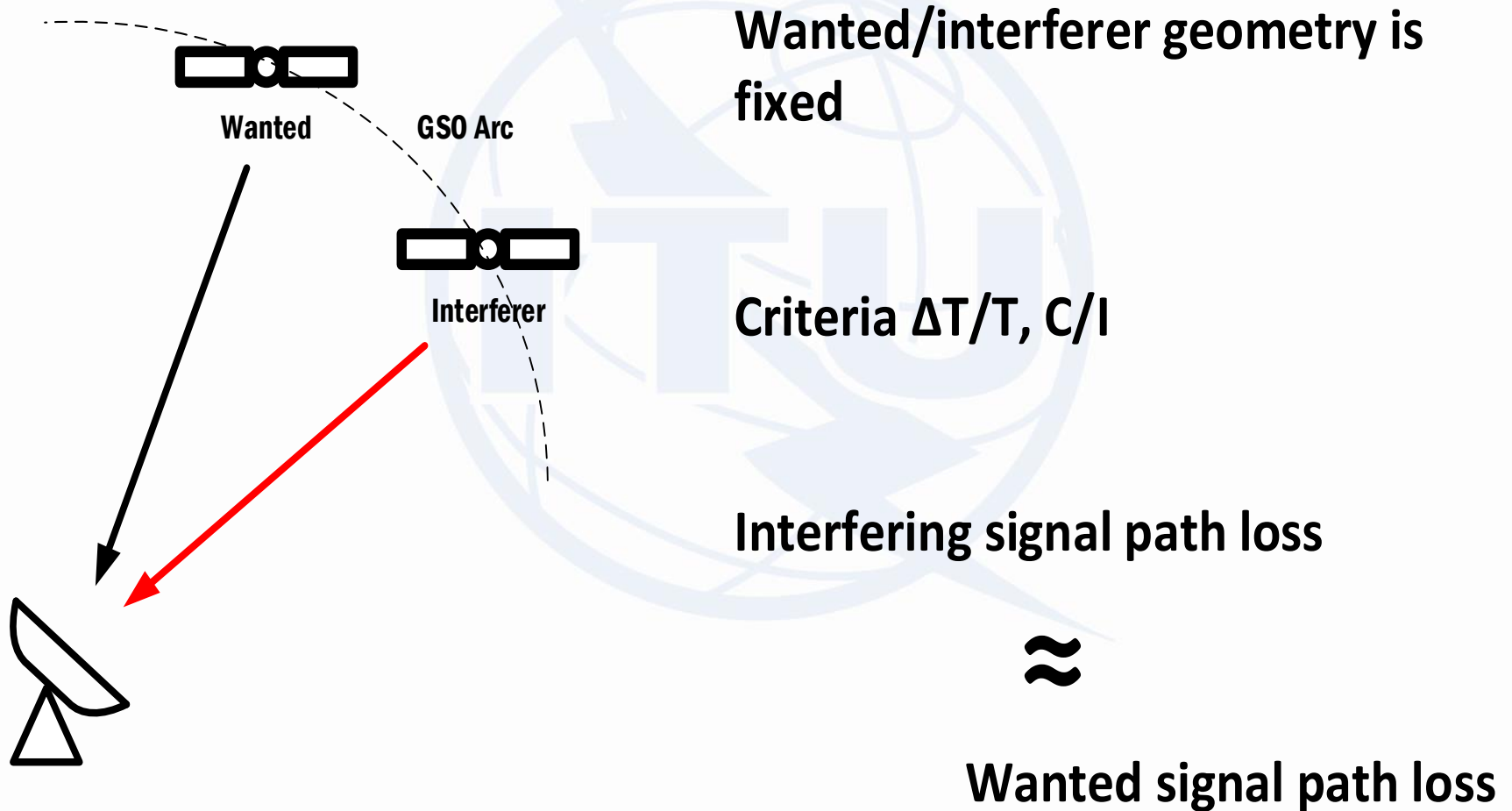
■ EPFD is calculated:

- Downlink (at the input of GSO earth station receiver)
- Uplink (at the input of GSO space station receiver)
- Inter-satellite (at the input of GSO space station receiver)

$$epfd = 10 \log_{10} \left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4 \pi d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}} \right]$$

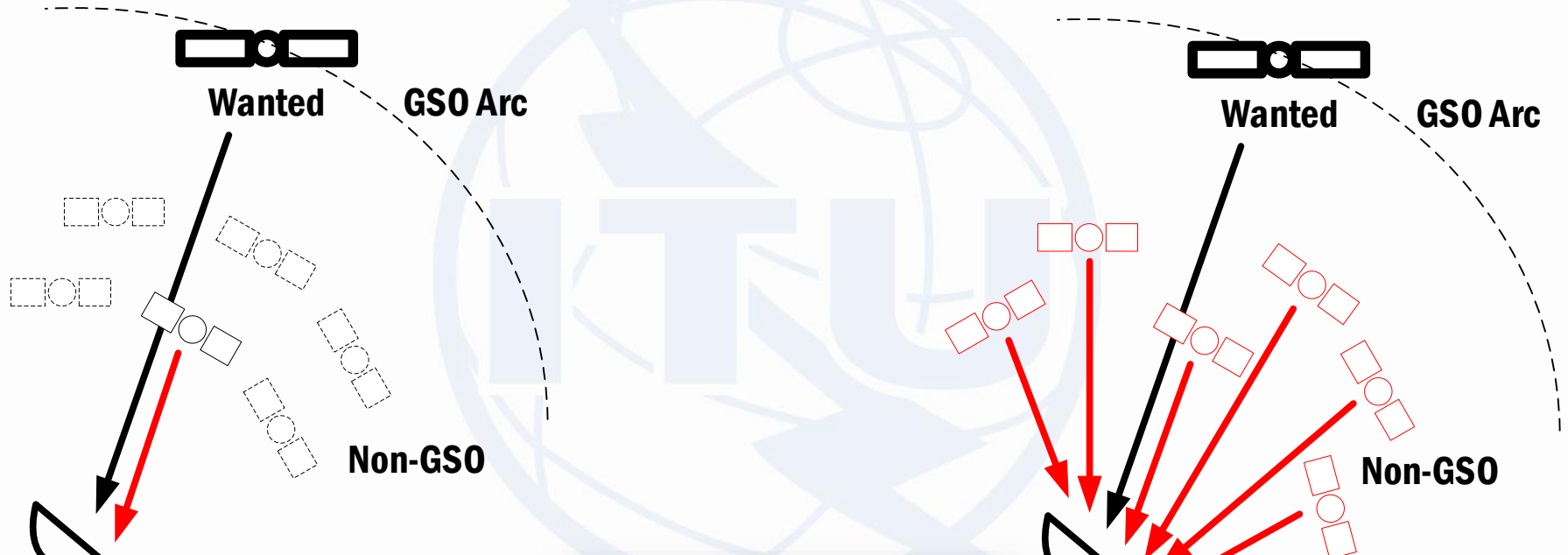
Why EPFD?

GSO to GSO



Why EPFD?

Non-GSO to GSO



**Constantly changing
wanted vs interferer
geometry**

**Aggregate effect of
interference from
several sources**

epfd _↓ (dB(W/m ²))	Percentage of time during which epfd _↓ may not be exceeded
-175.4	0
-174	90
-170.8	99
-165.3	99.73
-160.4	99.991
-160	99.997
-160	100

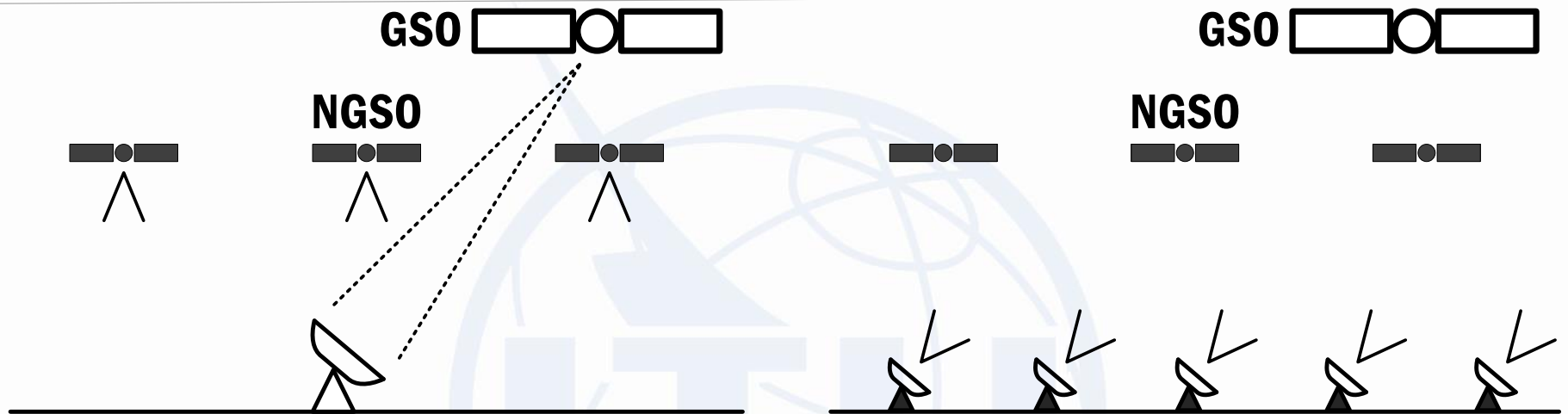
EPFD Limits Regulatory Framework

- Article **22 – Hard Limits to protect GSO from Non-GSO**
 - Hard EPFD limits enable non-GSO FSS systems to share frequencies with and protect GSO systems without requiring individual coordinations with all the systems worldwide
 - FSS non-GSO satellite systems shall comply with the EPFD limits contained in Tables **22-1A, 22-1B, 22-1C, 22-1D, 22-1E, 22-2 and 22-3** of RR Article **22**
 - ✓ Article 22 contains reference parameters of GSO stations to be protected

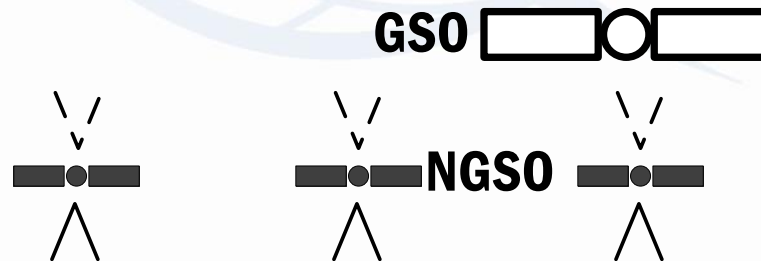
Frequency band (GHz)	epfd _↓ (dB(W/m ²))	Percentage of time during which epfd _↓ may not be exceeded	Reference bandwidth (kHz)	Reference antenna diameter and reference radiation pattern ⁷
10.7-11.7 in all Regions;	-175.4	0	40	60 cm Recommendation ITU-R S.1428-1
11.7-12.2 in Region 2;	-174	90		
12.2-12.5 in Region 3 and	-170.8	99		
12.5-12.75 in Regions 1 and 3	-165.3	99.73		
	-160.4	99.991		
	-160	99.997		
	-160	100		

EPFD on downlink

EPFD on uplink



EPFD on inter-satellite path



EPFD Limits Regulatory Framework

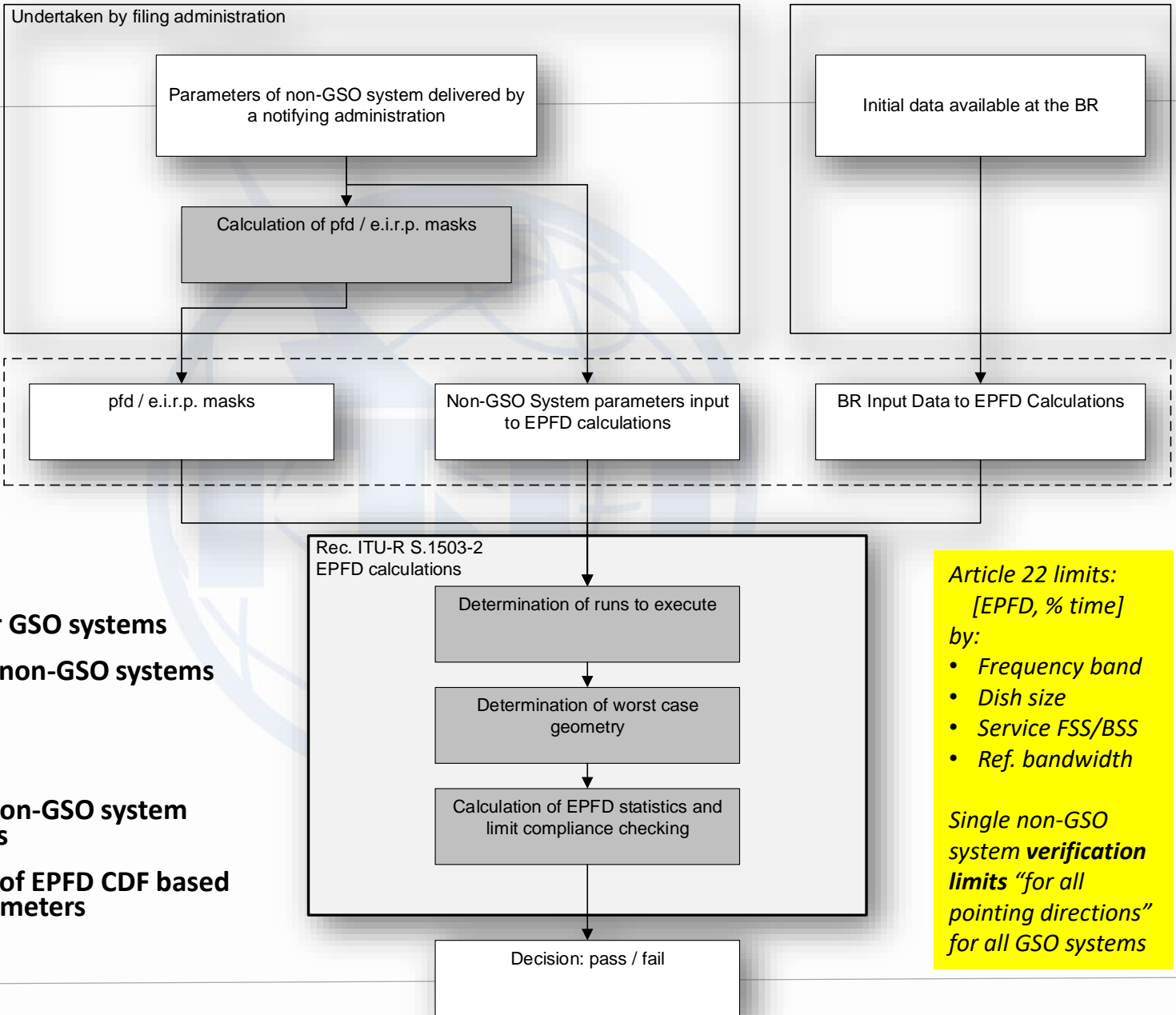
- **Article 9 – coordination trigger limits**
 - specific large earth station requires coordination under RR No. **9.7A** with respect to any existing non-GSO satellite systems using the coordination triggers in RR Appendix 5; or
 - FSS non-GSO satellite systems requires coordination under RR No. **9.7B** with respect to any large earth station (under certain conditions) using the coordination triggers in RR Appendix 5.
 - ✓ Coordination trigger limits enable protection of very large specific GSO earth stations

EPFD Limits Validation Tools

- Validation Software is developed in accordance with methodology in Recommendation ITU-R S.1503-2
- Resolution 85 (WRC-03) establishes intermediate arrangements until required software is developed
- “Qualified favourable” finding was given before availability of the software based on the commitment by notifying administration to fulfill Article 22 limits
- Findings under review
- Two parallel developments:
 - Transfinite Systems Ltd, developed in C++
 - Agenium, developed in C#
- Reasons for two developments - Confidence in results: useful for BR and ADMs to be able to check the result of more than one tool

Implementation of Resolution 85 (WRC-03)

- Circular Letter CR/414, 6 December 2016 contains details of examinations to be carried out in accordance with Resolution 85 (WRC-03).
 - The Bureau contacted (end of March 2017) individually each administration having submitted non-GSO systems in the FSS, and requested administrations to submit within three months:
 - “traditional” non-GSO parameters in Appendix 4 – orbit parameters, frequency assignments etc.
 - The PFD/EIRP* masks accounting for all the features of specific non-GSO systems arrangements
- * See also Rec. ITU-R S. 1503-2



App.4 “for space stations operating in a frequency band subject to Nos. 22.5C, 22.5D or 22.5F...”

Objectives:

- **Protection for GSO systems**
- **Flexibility for non-GSO systems**

Approach:

- **Measurable non-GSO system characteristics**
- **Computation of EPFD CDF based on these parameters**

Article 22 limits:
[EPFD, % time]
 by:

- *Frequency band*
- *Dish size*
- *Service FSS/BSS*
- *Ref. bandwidth*

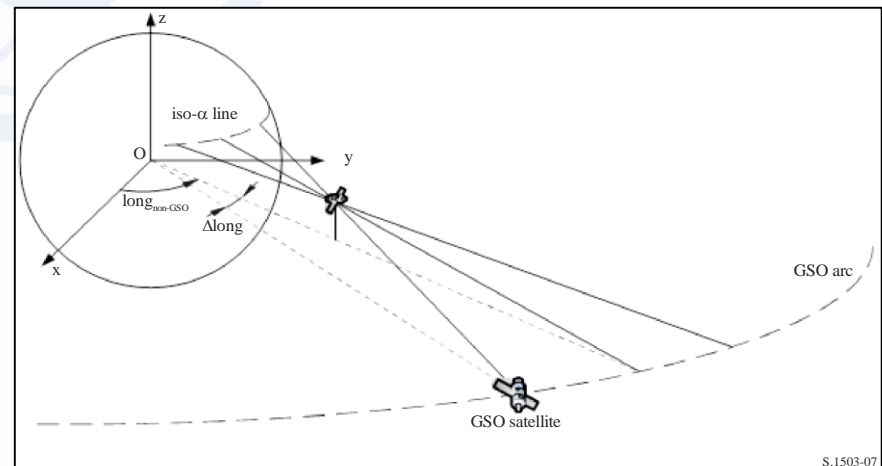
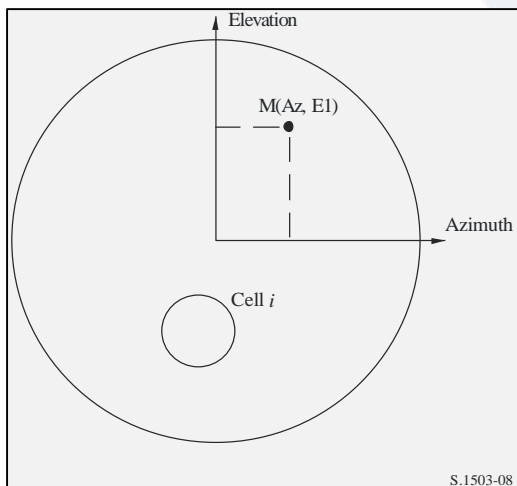
Single non-GSO system verification limits “for all pointing directions” for all GSO systems

Steps required to prepare the data for Article 22 Examination

- Get familiar with ITU-R Recommendations S. 1503-2/3
 - PART A – Assumptions
 - PART B – Input parameters
 - PART C – Generation of pfd/e.i.r.p. masks
 - PART D – General description of software algorithms

Steps required to prepare the data for Article 22 Examination - Masks

- Defines non-GSO station transmission “footprint”
 - For transmitting non-GSO earth station in form of eirp and off-axis eirp mask
 - For transmitting non-GSO satellite in form of pfd-mask given either in azimuth-elevation plane or relative to GSO exclusion zone
 - For transmitting non-GSO satellite in bi-directional frequency bands in form of eirp and off-axis eirp mask
- Masks are presented in XML-format and embedded in MS Access .MDB container
 - <https://www.itu.int/ITU-R/go/space-mask-XMLfile/en>
- Not included in BR IFIC SRS database
- Are published once examination of non-GSO satellite system is completed



Steps required to prepare the data for Article 22 Examination - Masks

- PFD Mask is a powerful instrument, its definition is based on consideration:
 - Mitigation techniques used towards GSO receiving stations
 - Variation of transmission per sub-satellite latitude
- Provided for each frequency band subject to EPFD
- Can have several different PFD-masks assigned to specific orbital planes or even satellites

Steps required to prepare the data for Article 22 Examination - Masks

- PFD Mask can take a form of:

PFD as a function of

- azimuth and elevation angles from a non-GSO space station towards a point on the Earth

or

PFD as a function of

- the separation angle α between a non-GSO space station and the GSO arc, as seen from any point on the surface of the Earth
 - the difference ΔL in longitude between the non-GSO sub-satellite point and the point on the GSO arc where the α angle is minimized
- $(\alpha, \Delta L)$ PFD Mask is used together with exclusion zone angle α supplied separately from the mask

Steps required to prepare the data for Article 22 Examination – SNS Data

Some other important parameters used:

- For Uplink,
 - The average distance on the Earth's surface between co-frequency beams (d) from the non-GSO system (km) and density of co-frequency non-GSO ES (*Density*)
 - Used to derive the number of earth stations operating within GSO footprint defined at -15 dB level. Number of ES within co-frequency beam:

$$NUM_ES = d * d * Density$$

- EIRP of representative ES:

$$REP_e.i.r.p. = ES_e.i.r.p. + 10\log_{10}(NUM_ES)$$

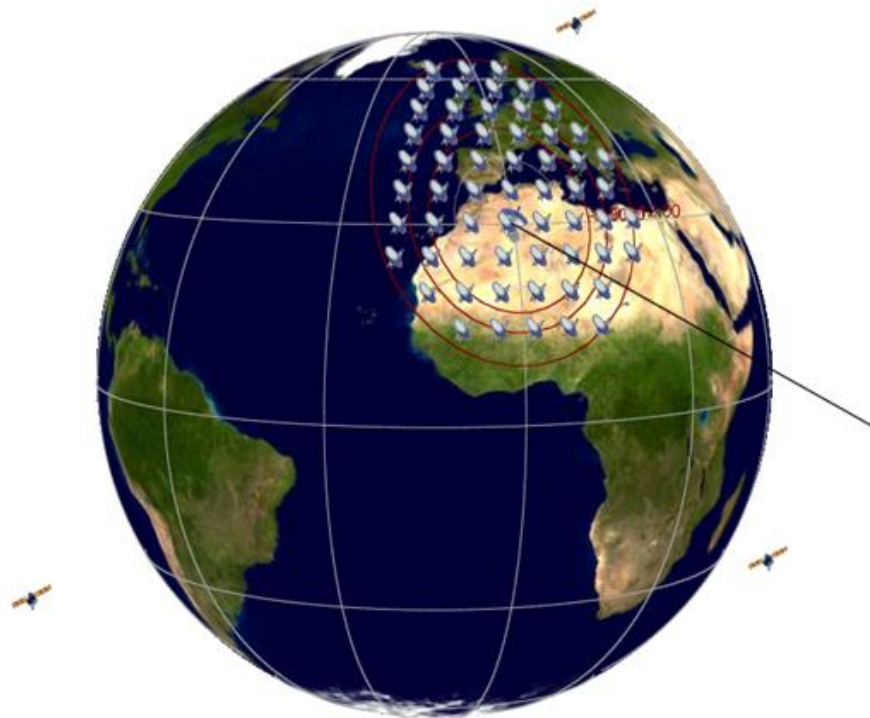
Defined in **non_geo** table, fields **avg_dist** and **density**

Steps required to prepare the data for Article 22 Examination

- Representative ES are then populated within GSO beam footprint with separation in longitude and latitude:

$$\Delta lat = \frac{d}{R_e}$$

$$\Delta long = \frac{d}{R_e \cos lat}$$



Steps required to prepare the data for Article 22 Examination

- For uplink and downlink

- Minimum elevation angle the non-GSO earth station when it is receiving or transmitting

Defined in **grp** table, field **elev_min**

- For Uplink,

- Maximum number of co-frequency tracked non-geostationary satellites receiving simultaneously

Defined in **non_geo** table, field **nbr_sat_td**

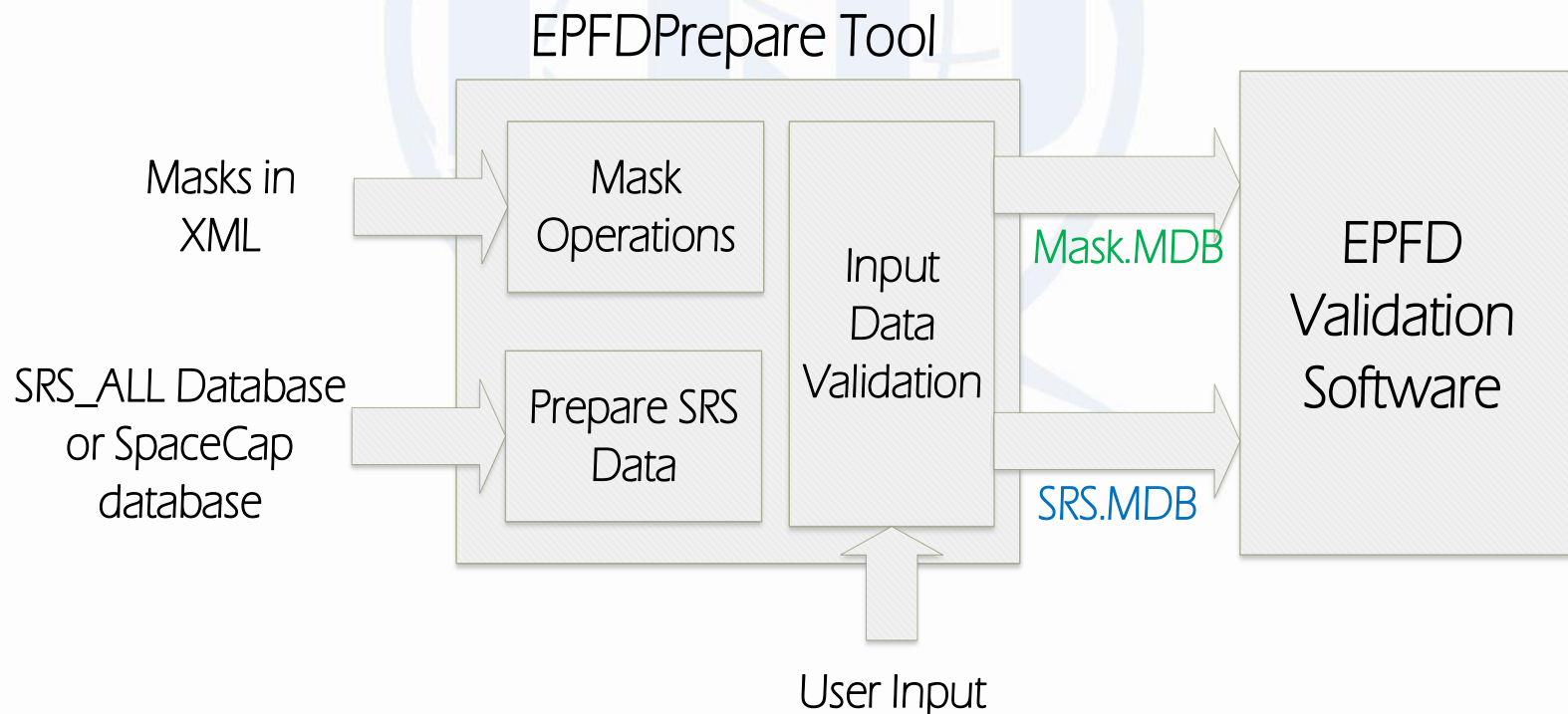
- For Downlink,

- Maximum number of non-geostationary satellites transmitting with overlapping frequencies to a given location within the latitude range

Defined in **sat_oper** table, fields **lat_fr**, **lat_to**, **nbr_opr_sat**

Compiling Data Set

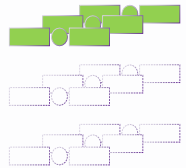
- Masks in XML format are stored in MDB file
- All other parameters are contained in SRS Database.
- To facilitate calculation it is advisable to extract a notice to a separate database only including 1 frequency assignment per each frequency band subject to Article 22, 9.7A, 9.7B examination.
- All data is compiled using EPFDPrepare Tool



Different scenarios – different databases

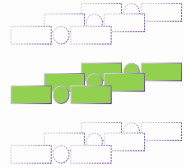
SNS MDB 1

Orbital configuration 1



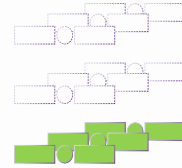
SNS MDB 2

Orbital configuration 2



SNS MDB 3

Orbital configuration 3



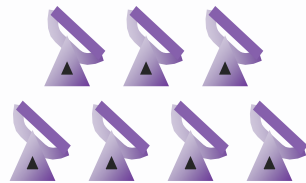
SNS MDB 4

Link type 1 (Service link)



SNS MDB 5

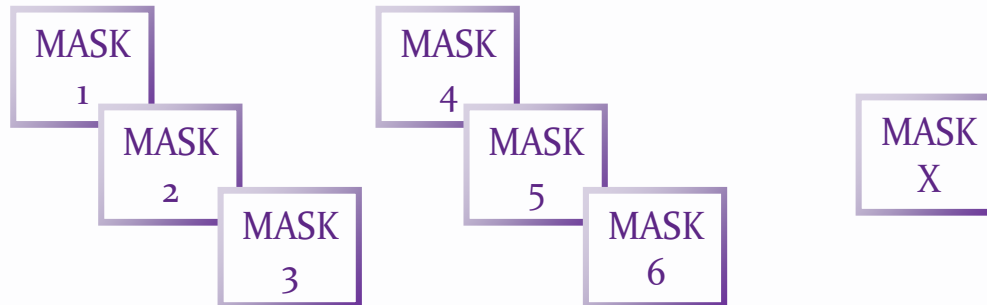
Link type 2 (User link)



SNS MDB X

Other – variation in
- GSO Avoidance angle,
- Operational latitudes,
- Number of satellites tracked simultaneously

MASKS MDB



Parameters defined at 'Notice' level (require separate database in case of variation):

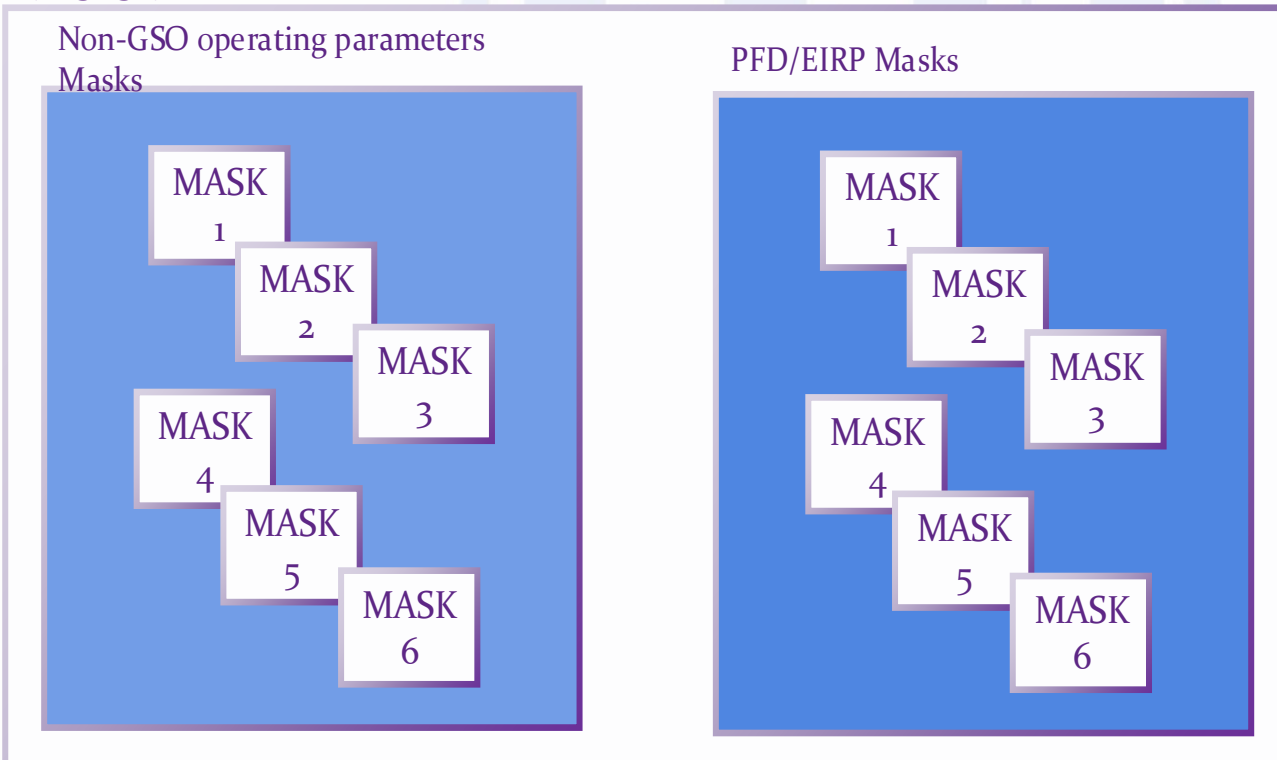
1. Earth stations distribution
2. Operational latitudes
3. Number of satellites tracked
4. GSO avoidance angle and method

Improvements in Rec. S. 1503-3

SNS MDB



MASKS MDB



Single SNS MDB
for all different
non-GSO
operating
scenarios

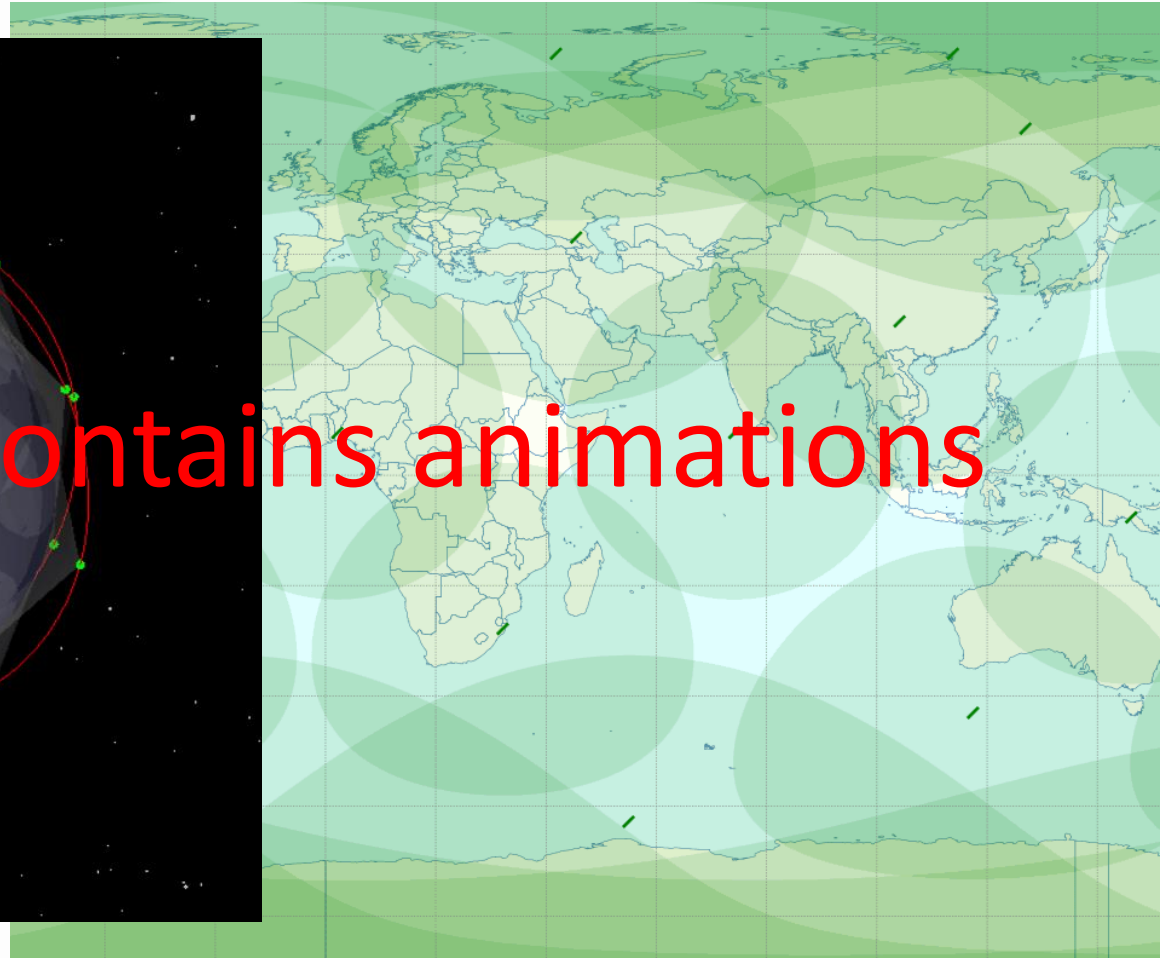
Test case

- LEO with orbit altitude of 1000 km
- 5 Orbital Planes with 5 satellites in each orbit
- Using steerable beams
- Minimum Elevation angle is 20 degrees
- PFD Mask in AzEl format
- Only 19.7-20.2 GHz band will be analyzed

Test case

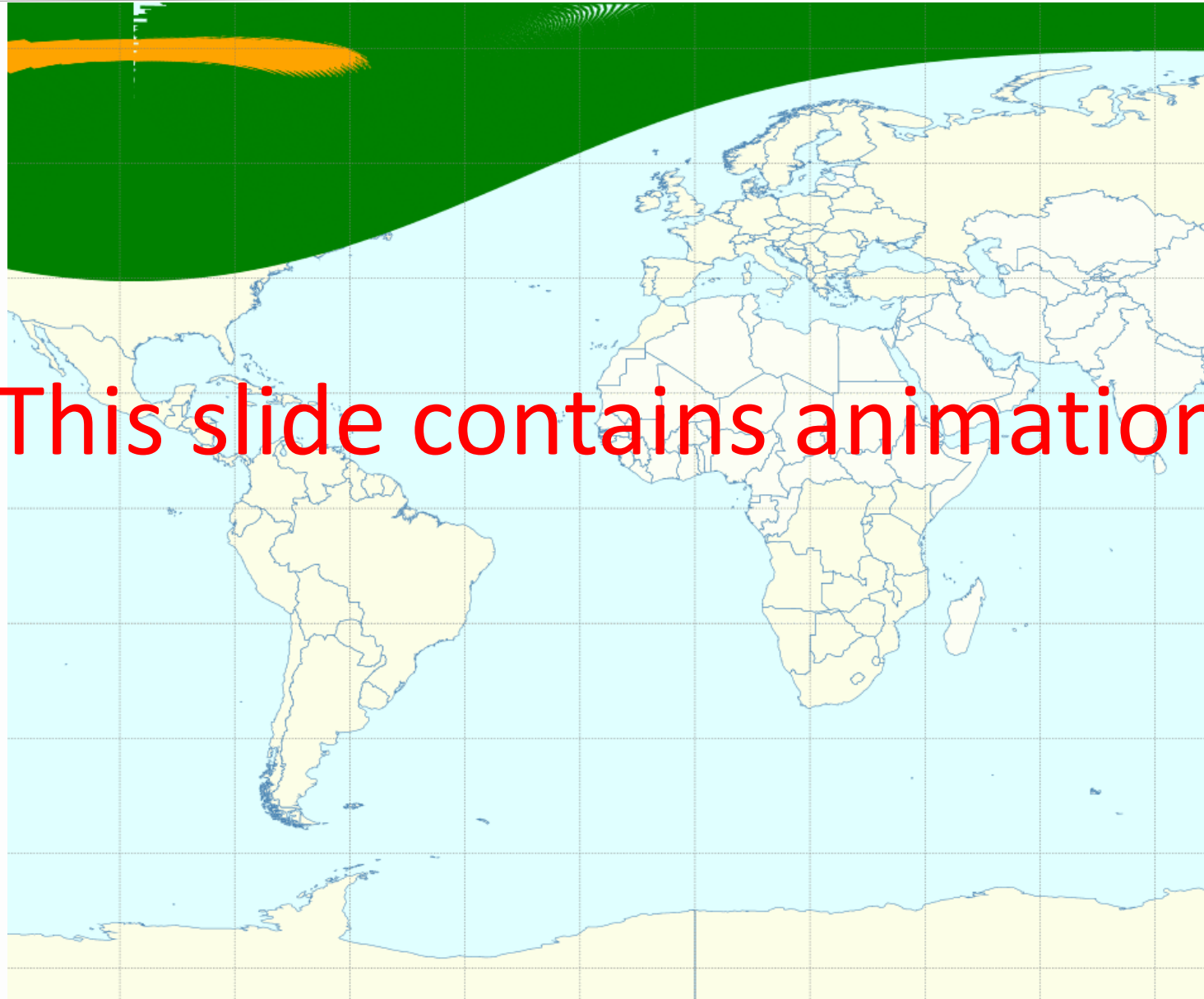


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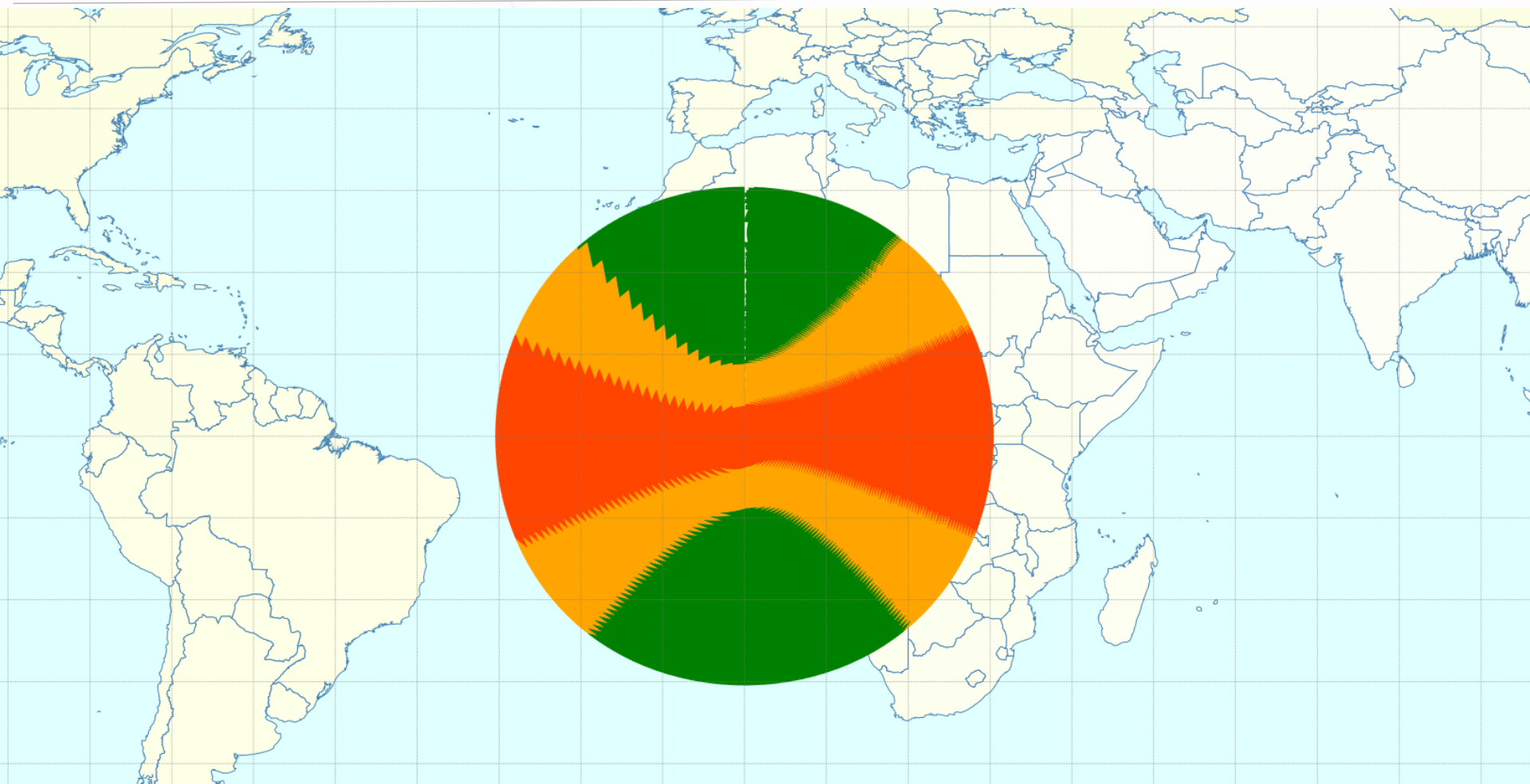
SaVi

Exclusion zone is defined in the mask



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Red zone (low transmission level) is 20 degrees



Defining mask

- Make sure that mask covers all ranges of latitudes, azimuth/elevation, alpha/deltaLongitude
- Exception, If same values are applicable to all latitudes of SSP provide only latitude=0 tables
- If appropriate mask is given but EPFD is still exceeded, consider increasing sampling of latitude, azimuth/elevation
- Note the worst-case geometry latitude identified by the software, include latitude table as close as possible to identified worst-case latitude
- For latitude, azimuth/elevation identified in EPFD software in a calculation step which can not be found in the mask, the software would use closest tables in the mask

Resources

ITU-R Recommendation S.1503-2

Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite system networks with limits contained in Article 22 of the Radio Regulations

EPFD software web-page

<http://www.itu.int/ITU-R/go/space-epfd/en>

EPFD Support Forum

<http://groups.itu.int/epfd/en-us/epfdforum.aspx>

epfd-support@itu.int

Exercise Overview

- Given the masks in XML-format and source SRS database to prepare input databases for EPFD validation
- Exercise 1: Using PFD-mask with no mitigation techniques applied
- Exercise 1: Using PFD-mask with restricted PFD-level in areas where there is a potential to affected victim GSO receiver

The logo features a stylized globe with latitude and longitude lines. Overlaid on the globe is the acronym 'EPFD' in large, bold, blue letters. The text 'Validation' is written in red, bold letters across the middle of the globe.

EPFD Validation

EXERCISES

Exercise setup

Locate EPFD exercise files on handout USB stick:

[USB drive]:\Space Workshop\Day 4\Non-GSO EPFD\

Install GIBC with EPFD Modules

From BR IFIC (Space Services) DVD-ROM or USB stick:

[USB drive]:\BRIFIC-2884_S\BR_Soft\GIBC\Setup.exe

or

<http://www.itu.int/en/ITU-R/software/Pages/epfd.aspx>

Exercise No. 1

Preparing data for EPFD Validation

Task:

Given an input data:

Database with non-GSO CR/C filing NSKY SRS_SOURCE.MDB

[USB drive]:\Space Workshop\Day 4\Non-GSO EPFD\SRS_SOURCE.MDB

XML Mask Data:

Downlink PFD Mask

[USB drive]:\Space Workshop\Day 4\Non-GSO
EPFD\Exercise_1_PFD_Mask_104_id_1.xml

Your task is:

- to prepare two input databases (SRS Data and Mask Data) required for EPFD Validation
- perform EPFD validation and review the results of EPFD validation.

Results are reproduced on the USB-stick:

[USB drive]:\Space Workshop\Day 4\Non-GSO EPFD\ReadyFiles\

Step-by-step guide for offline exercise is given in the [annex](#).

Exercise No. 2

Preparing data for EPFD Validation

Task:

Given:

Database NSKY_SRS.MDB prepared in first exercise

Adjusted XML Mask :

Downlink PFD Mask

[USB drive]:\Space Workshop\Day 4\Non-GSO
EPFD\Exercise_2_PFD_Mask_104_id_1.xml

Your task is:

- to prepare new Mask Data database required for EPFD Validation.
- perform EPFD validation and review the results of EPFD validation.

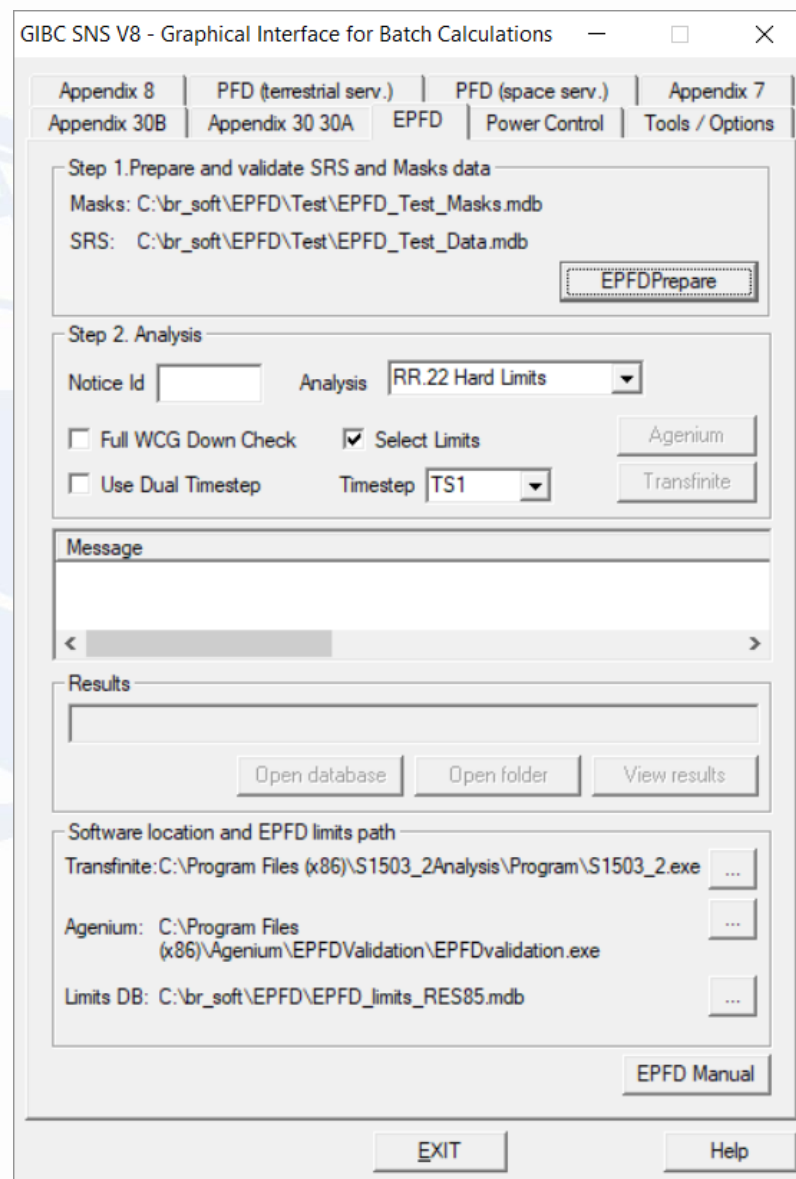
Results are reproduced on the USB-stick:

[USB drive]:\Space Workshop\Day 4\Non-GSO EPFD\ReadyFiles\

Step-by-step guide for offline exercise is given in the [annex](#).

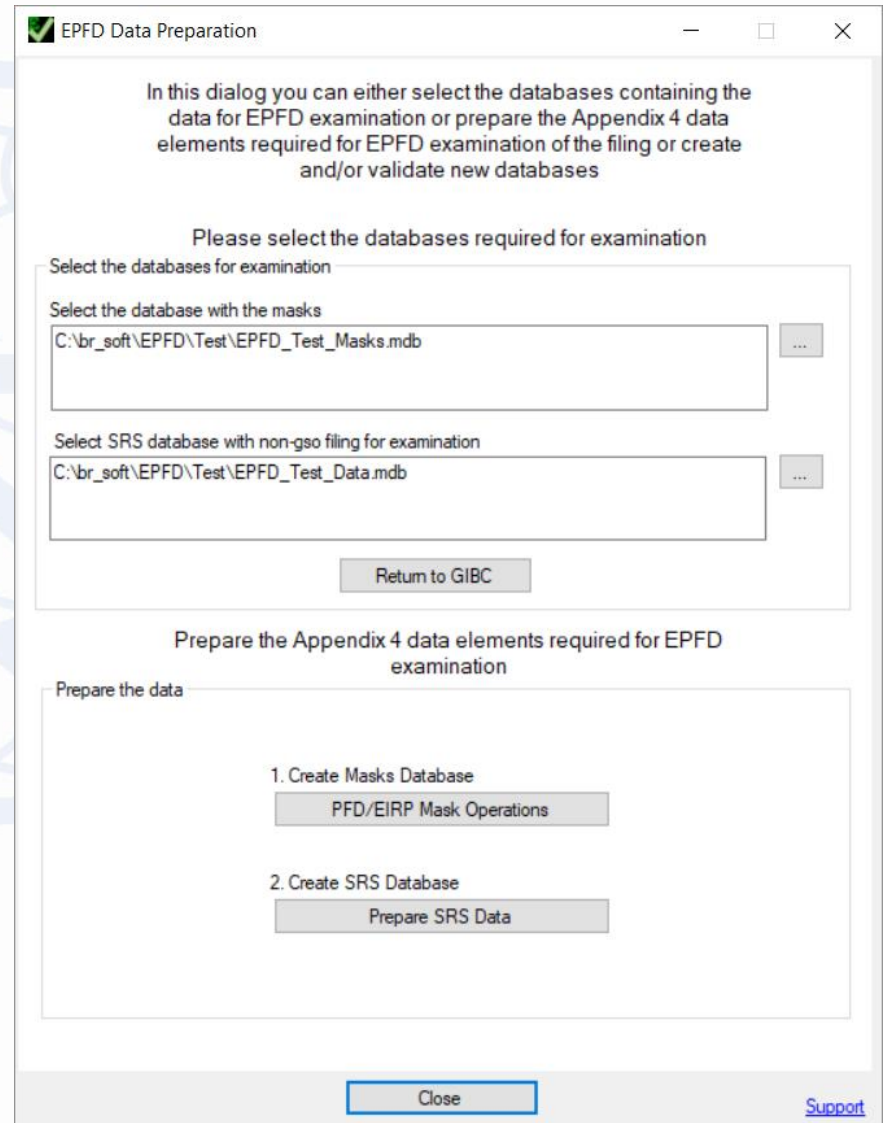
Start with GIBC

- Start GIBC
- Navigate to EPFD tab
- Start EPFDPrepare



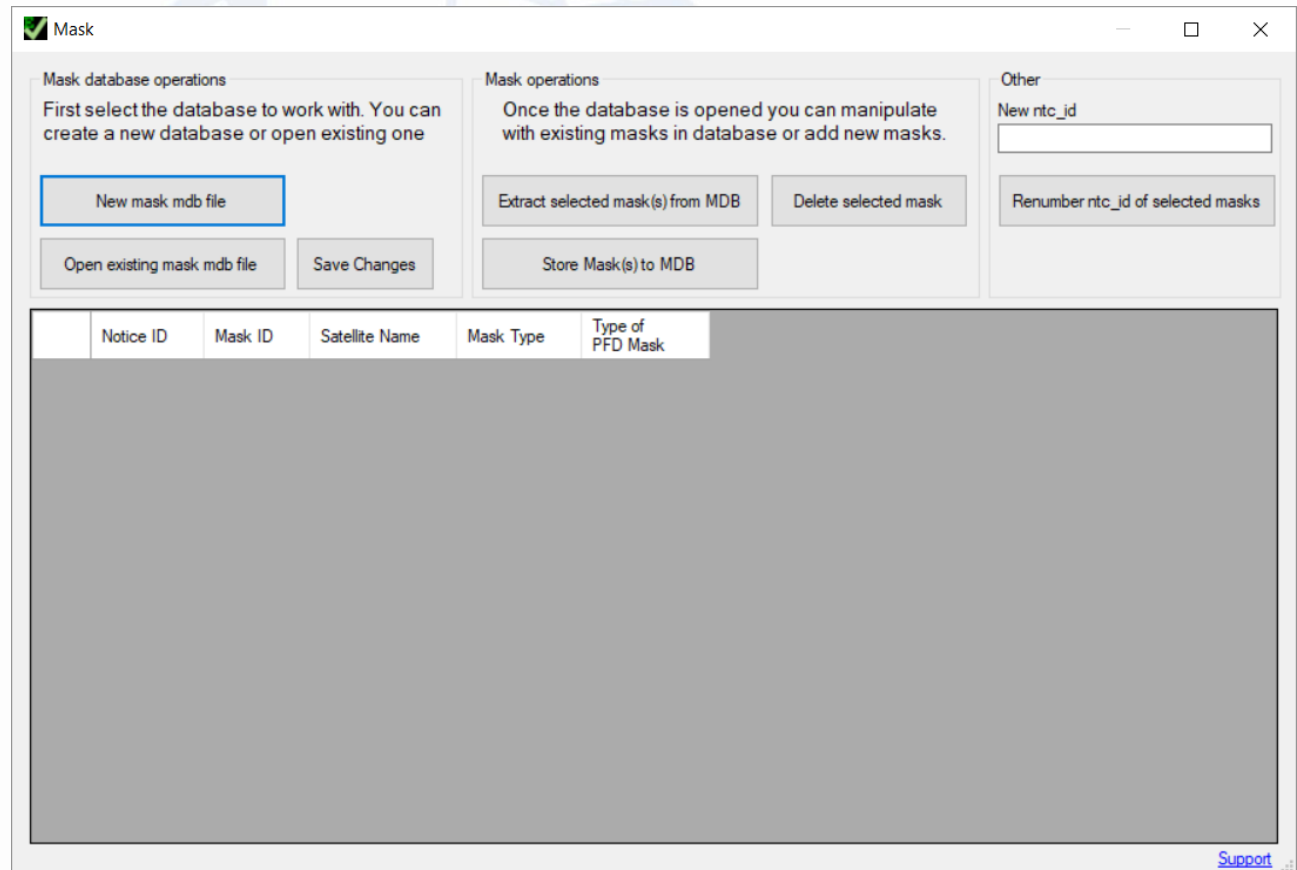
Prepare EPFD Input Data

- Select Create Masks Database



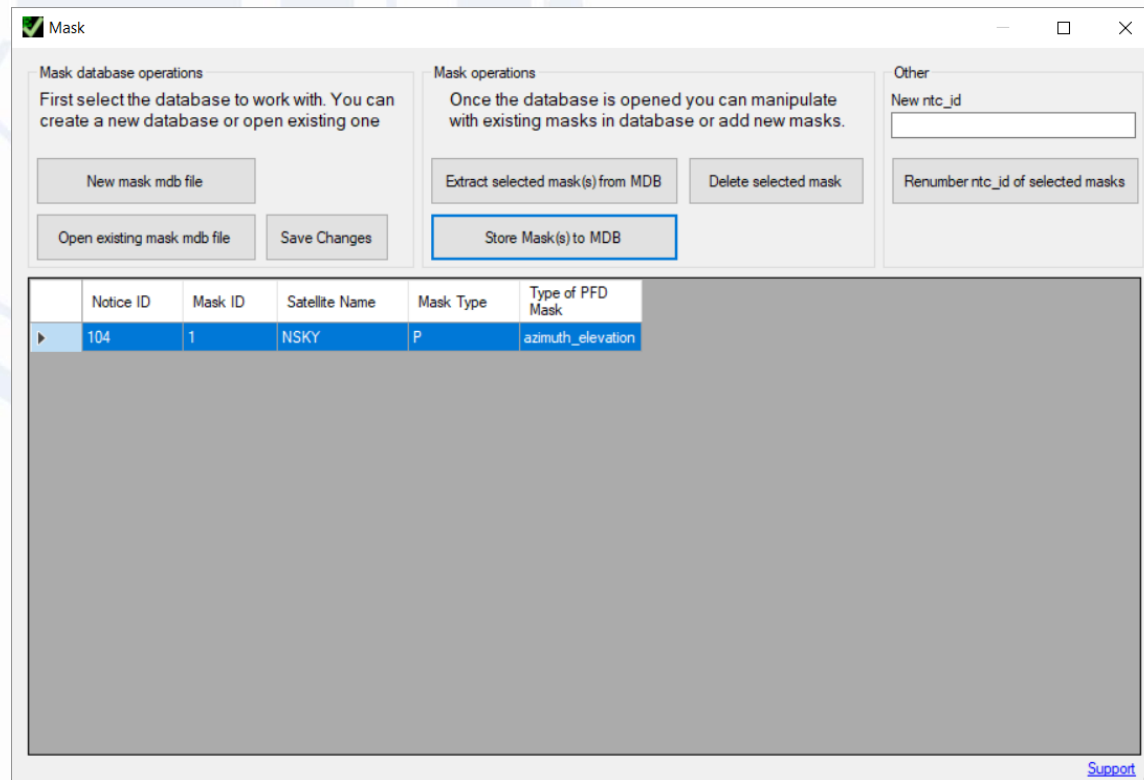
Prepare EPFD Input Data

- Click New Mask MDB File



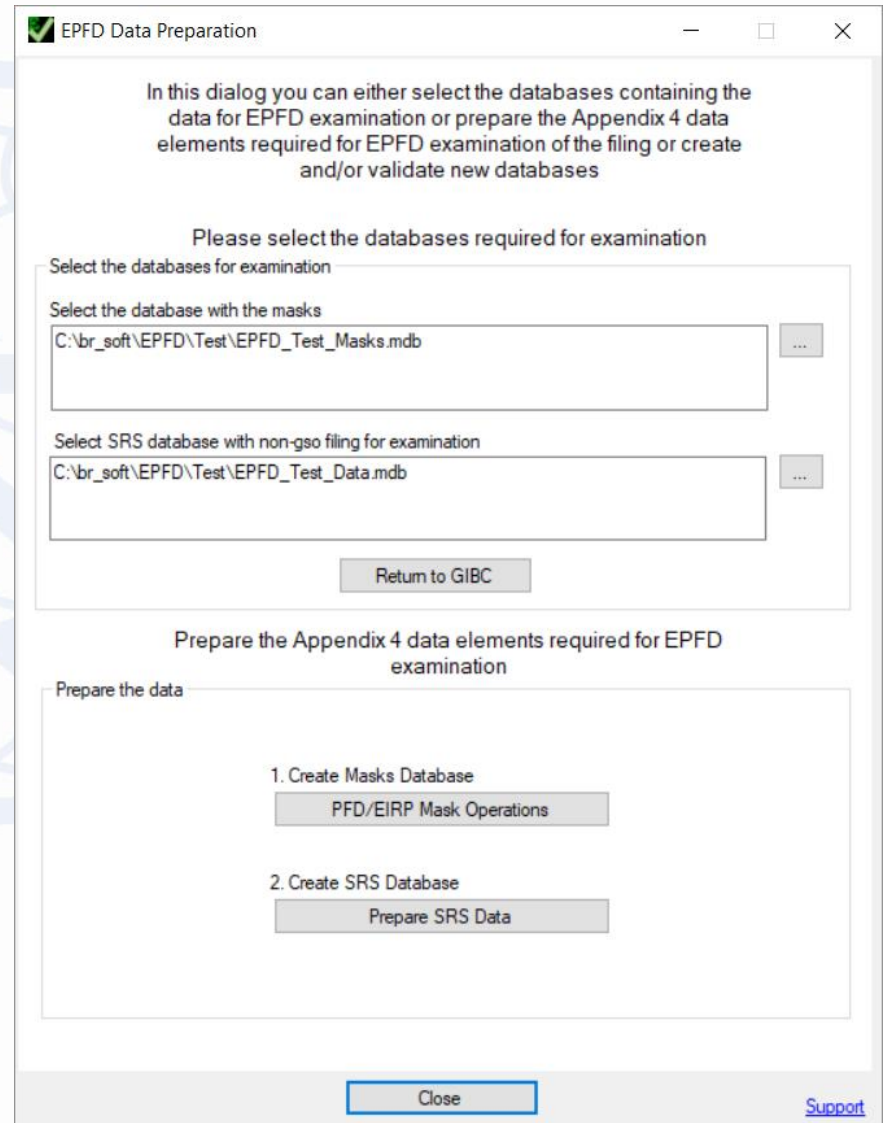
Prepare EPFD Input Data

- Click 'Save Changes'
- Save mask under the name NSKY_Mask_Exercise1.mdb
- Close the window to return to EPFD Prepare



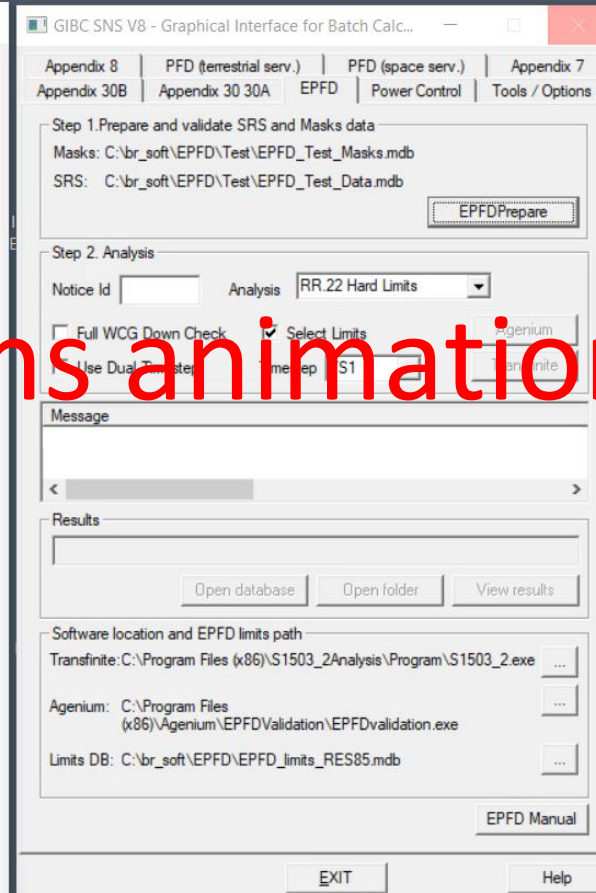
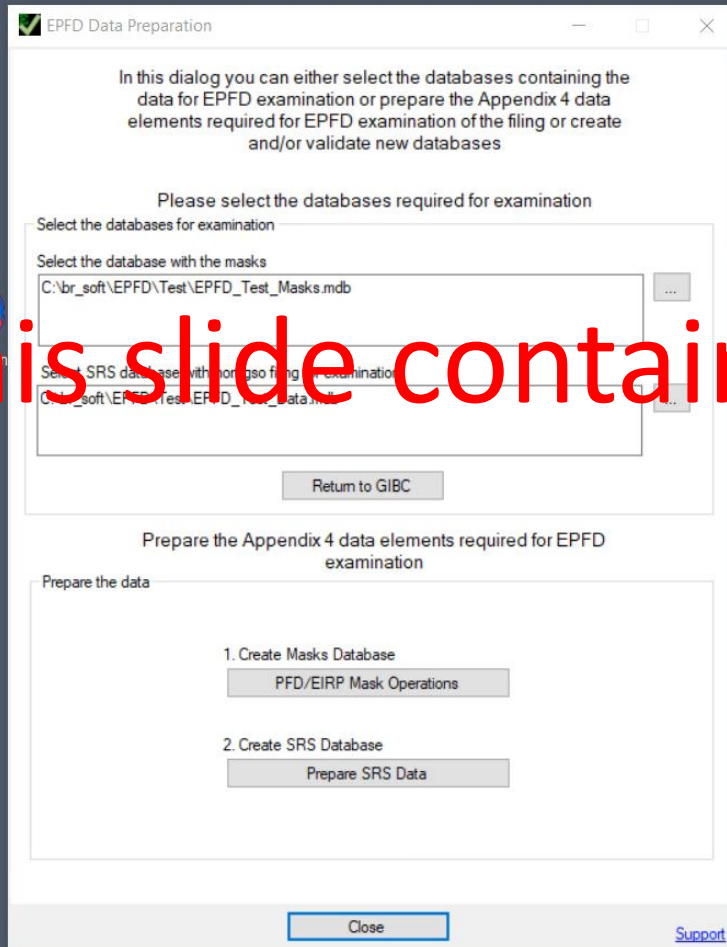
Prepare EPFD Input Data

- Select Prepare SRS Data



Prepare EPFD Input Data

- Select Prepare SRS Data



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Start EPFD

- Enter notice ID - **104**
- You can choose additional options:
 - Full WCG Down Check
 - Use Dual Timestep
- Check 'Use Dual Timestep' to speed-up calculations
- You can start calculations using Transfinite EPFD tool or Agenium EPFD Tool by clicking corresponding buttons.
- When finished click 'View Results'

GIBC SNS V8 - Graphical Interface for Batch Calculations

Appendix 8 | PFD (terrestrial serv.) | PFD (space serv.) | Appendix 7
Appendix 30B | Appendix 30 30A | EPFD | Power Control | Tools / Options

Step 1. Prepare and validate SRS and Masks data
Masks: M:\Space Workshop\Day 4\Non-GSO
SRS: M:\Space Workshop\Day 4\Non-GSO
EPFDPrepare

Step 2. Analysis
Notice Id: 104 | Analysis: RR.22 Hard Limits
 Full WCG Down Check | Select Limits | Agenium
 Use Dual Timestep | Timestep: TS1 | Transfinite

Message

Results
Open database | Open folder | View results

Software location and EPFD limits path
Transfinite: C:\Program Files (x86)\S1503_2Analysis\Program\S1503_2.exe
Agenium: C:\Program Files (x86)\Agenium\EPFDValidation\EPFDvalidation.exe
Limits DB: C:\br_soft\EPFD\EPFD_limits_RES85.mdb
EPFD Manual

EXIT | Help

View Results

The screenshot shows a software window titled "EPFD Results View". At the top left, there is a checkmark icon and the text "EPFD Results View". Below the title bar, there are two tabs: "Select input results" and "View results", with "View results" being the active tab. In the center, there is a label "Select results database" followed by a text box containing the path "C:\BR_TEX_RESULTS\EPFD\104\181126114408\EPFDRESULTS.MDB". To the right of the text box is a folder icon and a button labeled "Clear All Added". Below this, there is a label "Select Result to Display (use 'Ctrl'/'Shift' to make multiple selection)". A list box contains one item, "Art22", which is selected. At the bottom left, there is a checked checkbox labeled "Tree View". At the bottom right, there is a button labeled "Add Selected results".

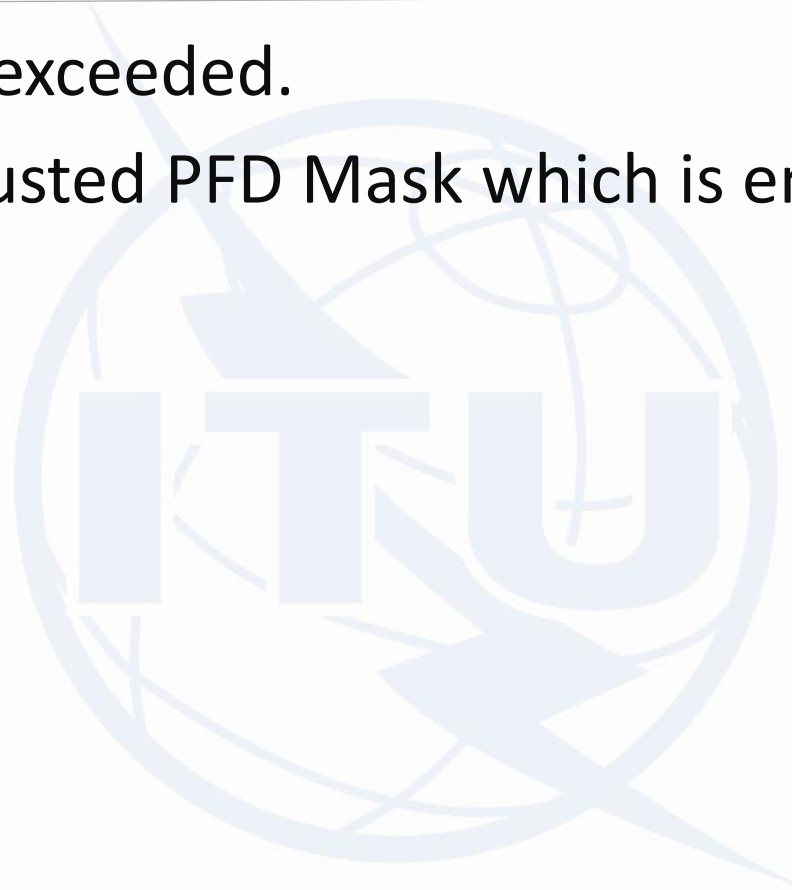
This slide contains animations

Exercise No. 1

Outcome

EPFD Limits are exceeded.

Need to use adjusted PFD Mask which is employing exclusion zones



Exercise No. 2

Repeat steps used to create NSKY_Mask_Exercise1.MDB
but use other XML mask

USB:\Space Workshop\Day 4\Non-GSO EPFD\Excercise_2_PFD_Mask_104_id_1.xml

Save MDB Mask file under NSKY_Mask_Exercise2.MDB

No need to create NSKY_SRS.MDB file, we will reuse
NSKY_SRS_Exercise1.mdb

Run EPFD Validation using:

NSKY_Mask_Exercise2.MDB

NSKY_SRS_Exercise1.MDB

Exercise No. 2

Results

EPFD Results View

Select input results View results

Select results database C:\BR_TEX_RESULTS\EPFD\104\181126115512\EPFDRESULTS.MDB

Select Result to Display (use 'Ctrl'/'Shift' to make multiple selection)

Art22

This slide contains animations

Tree View

Add Selected results



Thank you

epfd-support@itu.int