Space Connect
E1 – LEO Satellite Systems Fundamentals

SPECTRUM

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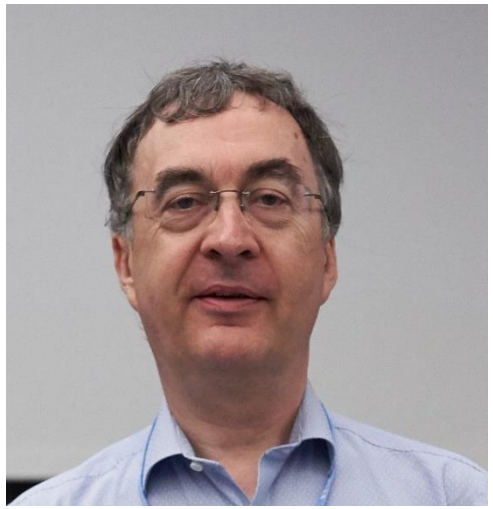

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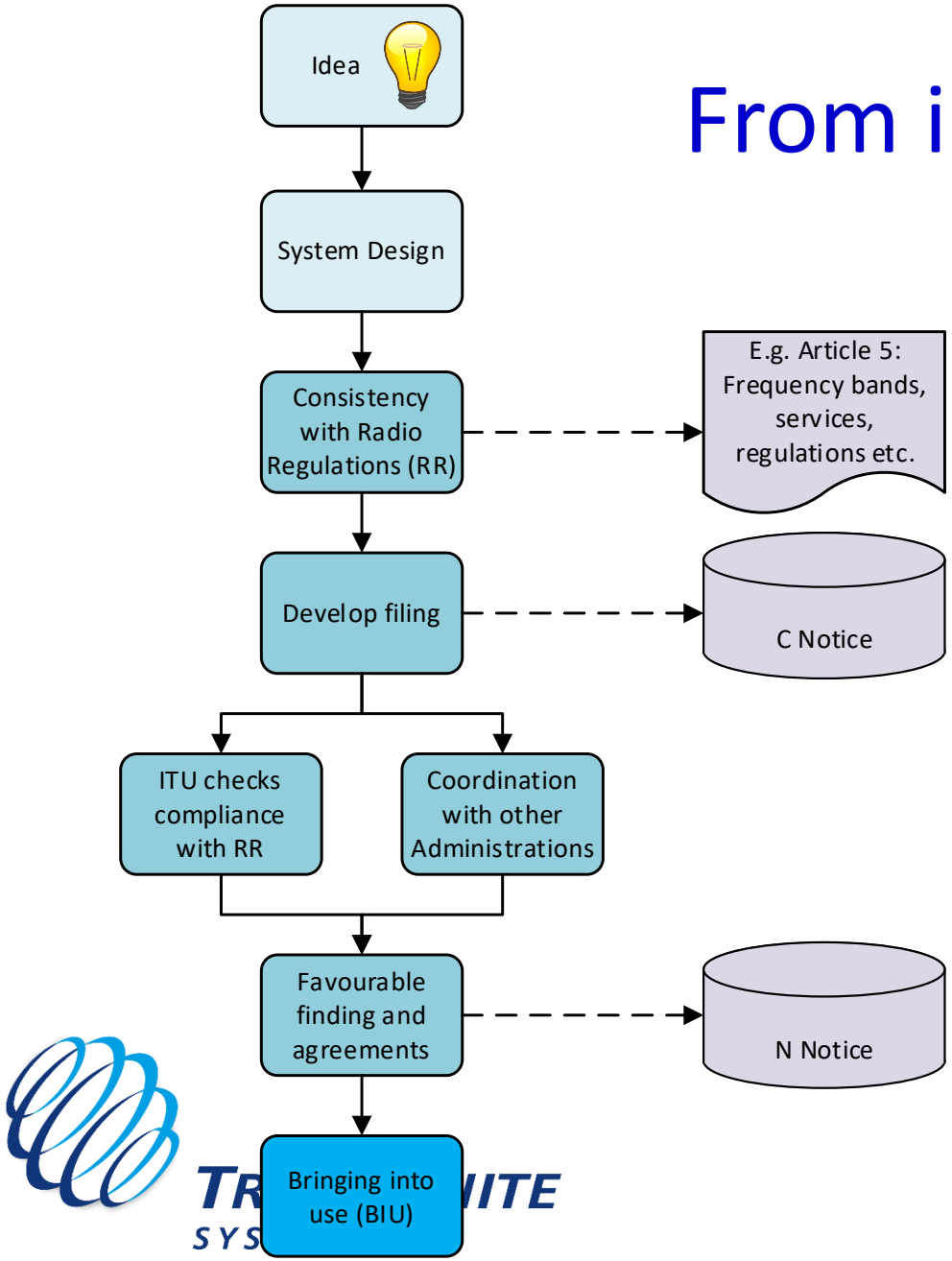
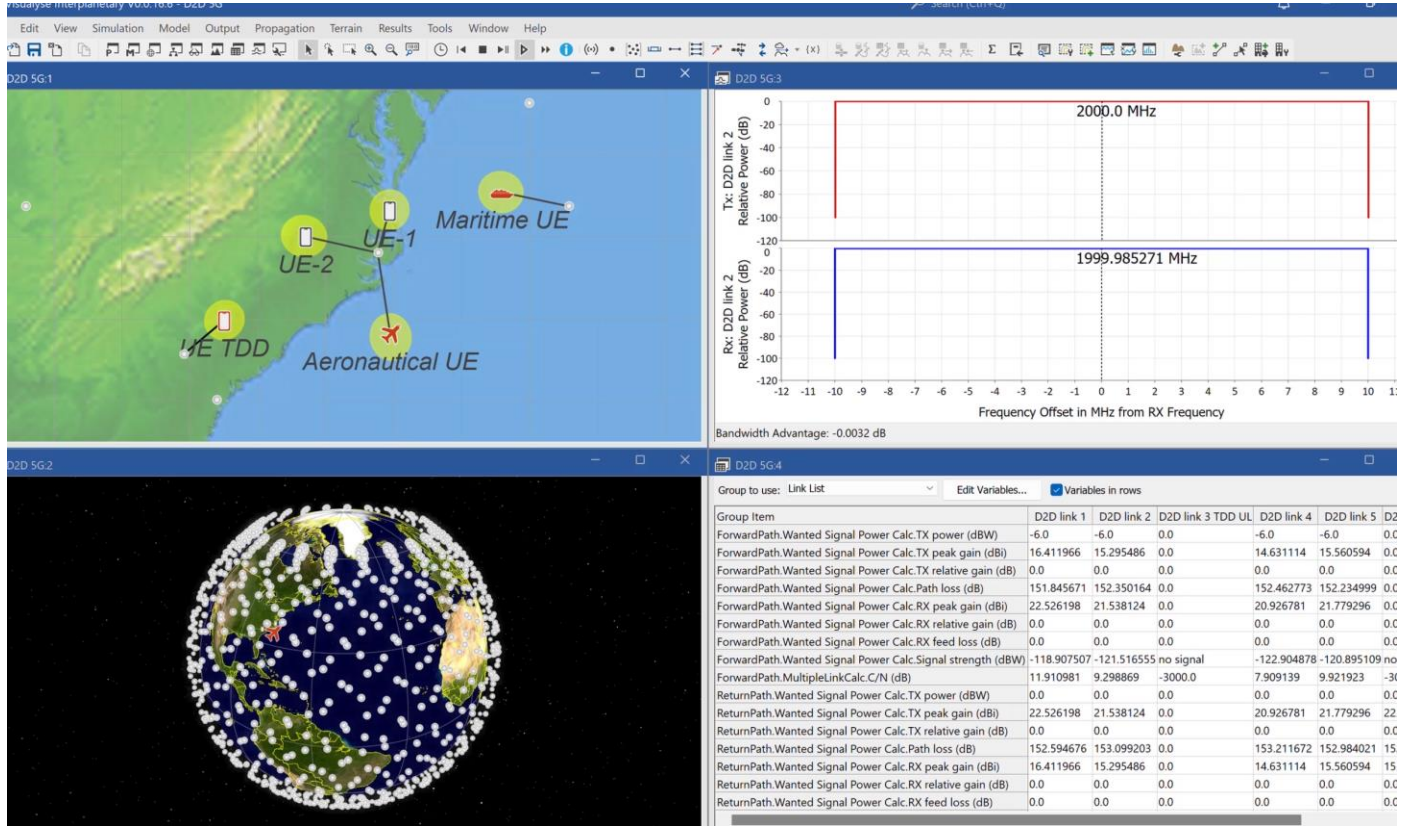
From idea to operation…





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Consistency with Radio Regulations (RR)

Radio Regulations

- **Radio Regulations** have legal status of international treaty
- Defines which **services** can transmit on what frequencies subject to specified constraints, as in Article 5 ⇒
- Satellite services include:
  - Fixed-satellite service (FSS)
  - Mobile-satellite service (MSS)
  - Space operation service
- For satellite services, also direction i.e. uplink or downlink
- Identification of **PRIMARY** or **Secondary** service
- Can be differences between **ITU Regions**:
  - Region 1: Europe and Africa including Russia
  - Region 2: Americas
  - Region 3: Asia including Iran and China.
- Important to check associated **footnotes**
- Other Articles need to be considered including:
  - Article 21: power flux density (PFD) limits to protect terrestrial services
  - Article 22: equivalent power flux density (EPFD) limits on non-GSO systems to protect GSO networks

1 710-2 170 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
1 710-1 930	FIXED MOBILE 5.384A 5.388 5.388A 5.149 5.341 5.385 5.386 5.387	
1 930-1 970 FIXED MOBILE 5.388 5.388A	**1 930-1 970** FIXED MOBILE 5.388 5.388A Mobile-satellite (Earth-to-space)	**1 930-1 970** FIXED MOBILE 5.388 5.388A
1 970-1 980	FIXED MOBILE 5.388 5.388A	
1 980-2 010	FIXED MOBILE 5.388 MOBILE-SATELLITE (Earth-to-space) 5.351A 5.389A 5.389B 5.389F	
2 010-2 025 FIXED MOBILE 5.388 5.388A	**2 010-2 025** FIXED MOBILE 5.388 MOBILE-SATELLITE (Earth-to-space) 5.389C 5.389E	**2 010-2 025** FIXED MOBILE 5.388 5.388A
2 025-2 110	SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) FIXED MOBILE 5.391 SPACE RESEARCH (Earth-to-space) (space-to-space) 5.392	

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Develop filing

The Filing

- Initial submission: the Advanced Publication Information "API" or Coordinate Request "CR/C" filing
  - Inform other **administrations** (countries) & operators of characteristics of proposed system
- When checks are complete: the Notification filing
  - Record final system parameters in the Master International Frequency Register or **MIFR**
- See Appendix 4 for parameters and Articles 9 and 11 for process
- Submitted by administrations, on behalf of operators
- Position in queue gives a degree of priority over later filings
- Can be up to 7 years between initial submission and operations for unplanned bands
- Filing contains information such as:
  - Orbit parameters using Keplerian elements, identification of orbit planes, whether sun-synchronous etc.
  - Antenna parameters such as dish size, peak gain, beamwidth, gain pattern
  - Link attributes such as power / power density, bandwidths, frequencies, thresholds
- Tools such as SpaceCap from the ITU to create, edit, view
- Separate databases for some examinations, such as EPFD examination against limits in Article 22

Items in Appendix	*A - GENERAL CHARACTERISTICS OF THE SATELLITE NETWORK OR SYSTEM, EARTH STATION OR RADIO ASTRONOMY STATION*
A.4.b.4	**For each orbital plane, where the Earth is the reference body:**
A.4.b.4.a	the angle of inclination (i_j) of the orbital plane with respect to the Earth's equatorial plane ($0° \leq i_j < 180°$)
A.4.b.4.b	the number of satellites in the orbital plane
A.4.b.4.c	the period
A.4.b.4.d	the altitude, in kilometres, of the apogee of the space station
A.4.b.4.e	the altitude, in kilometres, of the perigee of the space station
A.4.b.4.f	the minimum altitude of the space station above the surface of the Earth at which any satellite transmits
A.4.b.4.g	**Not used**
A.4.b.4.h	the initial phase angle (ω_i) of the i-th satellite in its orbital plane at reference time $t = 0$, measured from the point of the ascending node ($0° \leq \omega_i < 360°$)

Steam 1

orbit

ntc_id	orb_id	nbr_sat_pl	right_asc	inclin_ang	prd_ddd	prd_hh	prd_mm	apog	apog_exp	perig	perig
114520273	1	99	0	53	0	1	48	1150	0	1150	
114520273	2	99	11.3	53	0	1	48	1150	0	1150	
114520273	3	99	22.5	53	0	1	48	1150	0	1150	
114520273	4	99	33.8	53	0	1	48	1150	0	1150	
114520273	5	99	45	53	0	1	48	1150	0	1150	
114520273	6	99	56.3	53	0	1	48	1150	0	1150	
114520273	7	99	67.5	53	0	1	48	1150	0	1150	
114520273	8	99	78.8	53	0	1	48	1150	0	1150	
114520273	9	99	90	53	0	1	48	1150	0	1150	
114520273	10	99	101.3	53	0	1	48	1150	0	1150	
114520273	11	99	112.5	53	0	1	48	1150	0	1150	
114520273	12	99	123.8	53	0	1	48	1150	0	1150	
114520273	13	99	135	53	0	1	48	1150	0	1150	
114520273	14	99	146.3	53	0	1	48	1150	0	1150	
114520273	15	99	157.5	53	0	1	48	1150	0	1150	
114520273	16	99	168.8	53	0	1	48	1150	0	1150	
114520273	17	99	180	53	0	1	48	1150	0	1150	
114520273	18	99	191.3	53	0	1	48	1150	0	1150	
114520273	19	99	202.5	53	0	1	48	1150	0	1150	
114520273	20	99	213.8	53	0	1	48	1150	0	1150	
114520273	21	99	225	53	0	1	48	1150	0	1150	
114520273	22	99	236.3	53	0	1	48	1150	0	1150	
114520273	23	99	247.5	53	0	1	48	1150	0	1150	
114520273	24	99	258.8	53	0	1	48	1150	0	1150	
114520273	25	99	270	53	0	1	48	1150	0	1150	
114520273	26	99	281.3	53	0	1	48	1150	0	1150	

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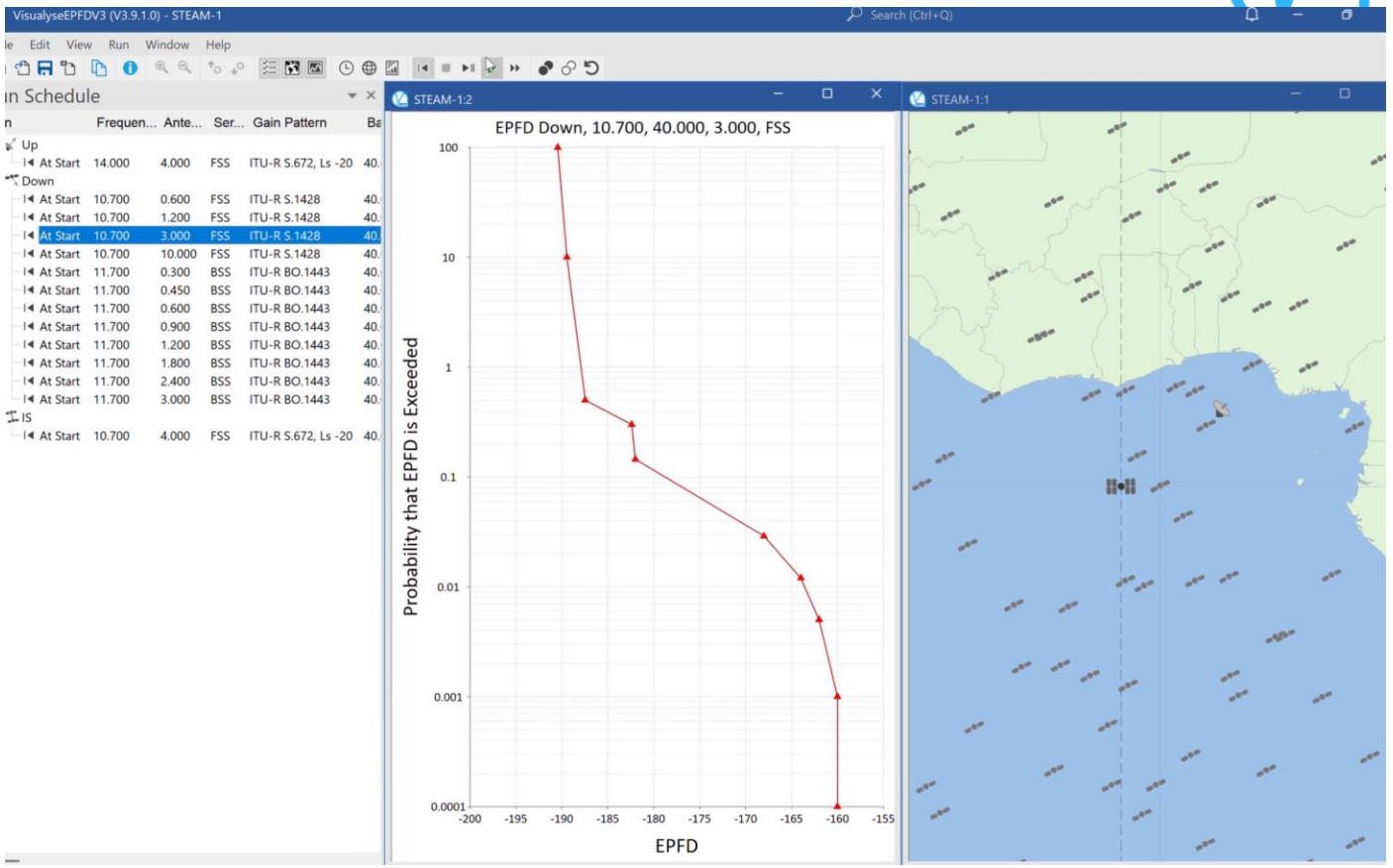
ITU checks compliance with RR

ITU Checks

- The ITU checks filings against the Radio Regulations
- Checks frequencies and services consistent with Article 5
- Checks PFD against thresholds in Article 21
- Checks EPFD against limits in Article 22, where EPFD statistics calculated using algorithm in Recommendation ITU-R S.1503
  - Example of this here ⇒
- Publishes its findings:
  - Favourable ✓
  - Unfavourable ✘
- EPFD examination can lead to a qualified favourable finding



EPFD examination of STEAM-1 filing using algorithm in Recommendation ITU-R S.1503 and EPFD limits in Article 22 using:

- EPFD SRS database
- EPFD PFD mask database

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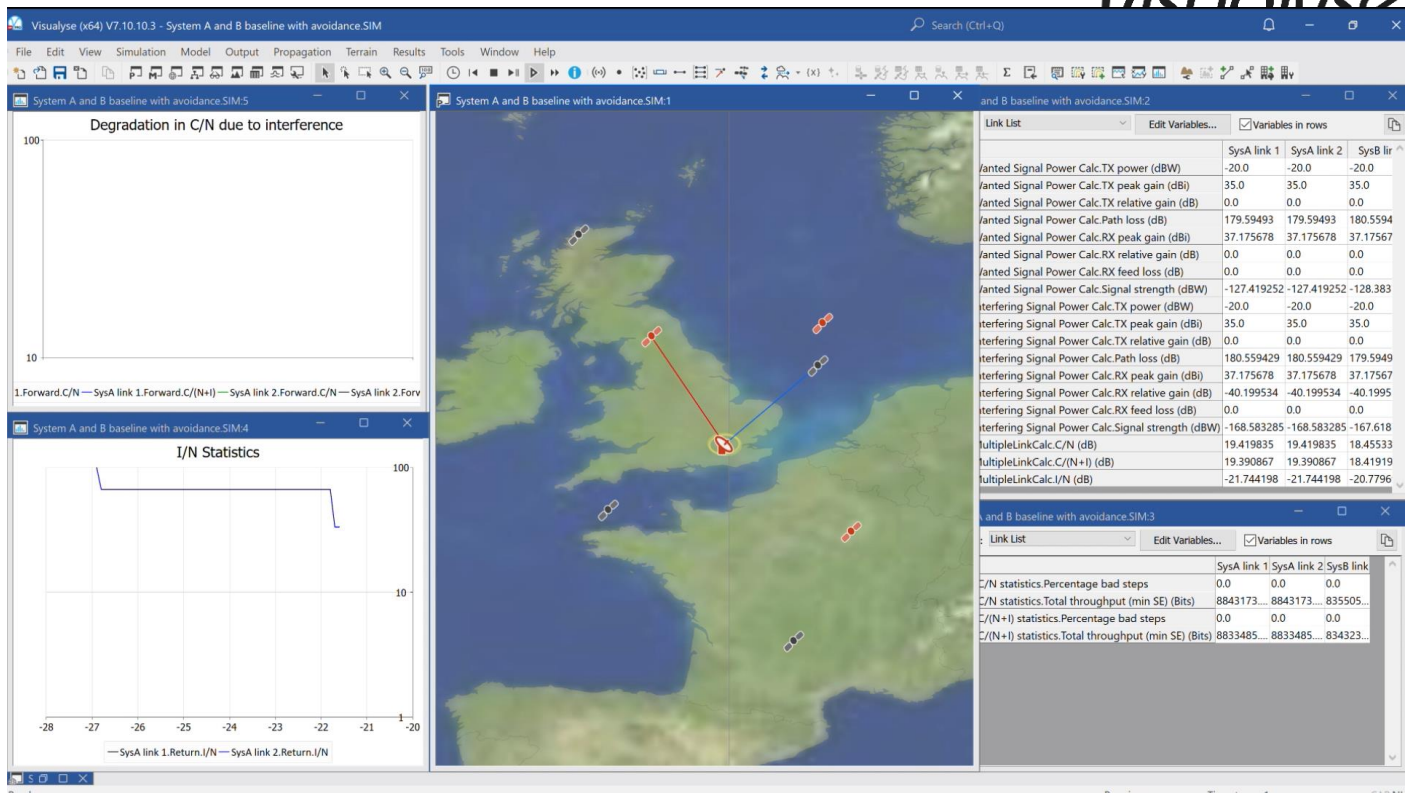
Coordination with other Administrations

Coordination and Consultations

- Administrations check new filings for potential issues
- International Frequency Information Circulars (IFICs) are published by the ITU every two weeks
- Procedures in Article 9 including whether required
- Coordination criteria in Appendix 5
  - For example, No. 9.12, non-GSO to non-GSO, the threshold / condition is bandwidth overlap
- Coordination is between Administrations with support from operators
  - Can request support from ITU
- Methodology and data to be agreed between the parties involved
- Ongoing process & can also be consultation meetings to manage aggregate interference:
  - Resolution 609: RNSS into ARNS
  - Resolution 76: Non-GSO into GSO



Analysis of avoid-pointing as coordination method between non-GSO satellite networks based upon document WP 4A/383 from the cycle WRC-19 to WRC-23

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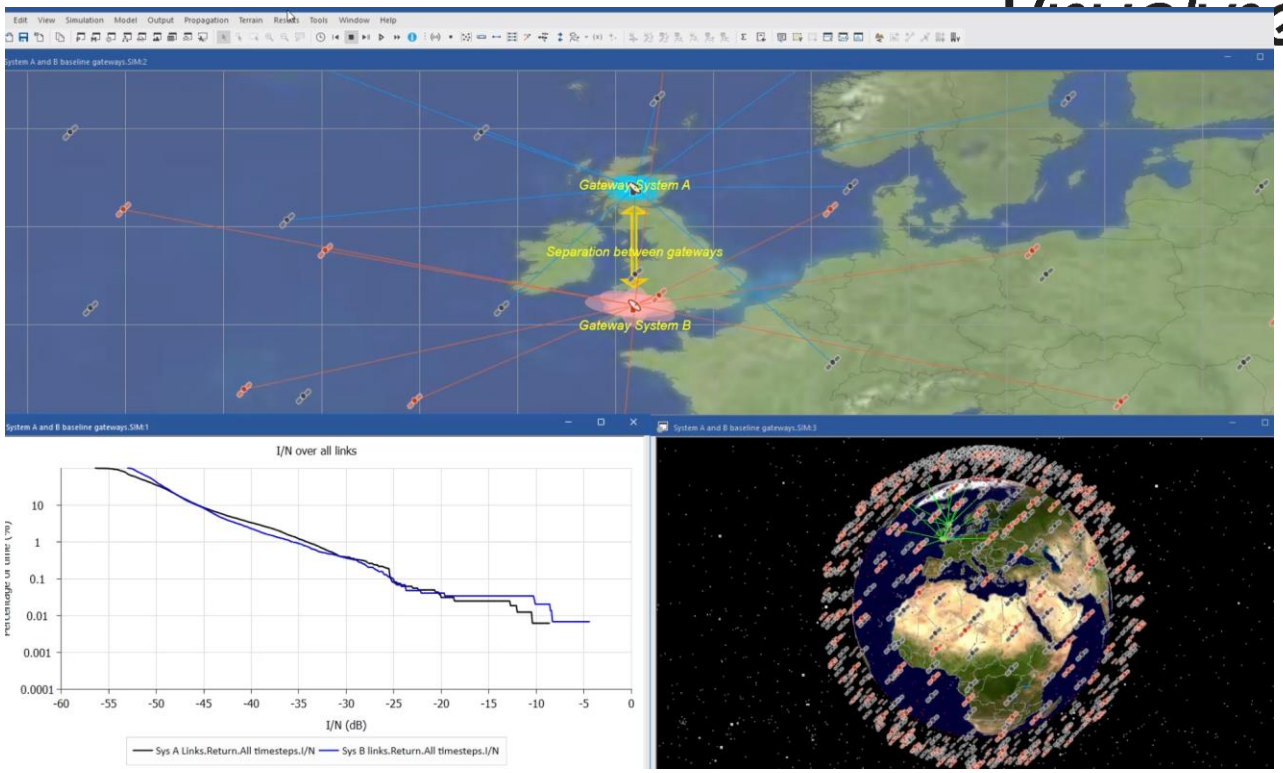
Coordination Techniques and Methodologies

- ITU-R Recommendations are a useful source of information and standards:
  - Gain patterns e.g. S.1528
  - Thresholds e.g. S.1323
  - Modelling methods e.g. S.1325
  - Mitigation methods e.g. S.1431
- Range of techniques available to facilitate coordination between satellite systems:
  - Avoid pointing
  - Geographic separation
  - Frequency separation
  - Time separation
  - Use of alternate polarization
  - Management of EIRP/PFD
  - Improved antenna discrimination
  - Orbit parameters
  - Acceptance of higher levels of interference
  - Etc.



Analysis of separation distance between non-GSO constellation gateways based upon document WP 4A/383 from the cycle WRC-19 to WRC-23

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Novel Space Applications

- In most cases, can operate new systems under existing Radio Regulations
  - Very flexible system
- If not, would require modifications to the Radio Regulations (RR)
- Modifications to the RR occur at World Radiocommunication Conferences (WRCs), which occur every 4 years
- Agenda for next WRC-27 contains a many satellite topics
- WRC-27 will discuss and agree the Agenda for WRC-31
- Could operate under 4.4

  4.4 …shall not cause harmful interference to, and shall not claim protection from harmful interference…
- Should only be used under exceptional circumstances
- Changes to ITU-R Recommendations typically quicker, not tied to the WRC cycle

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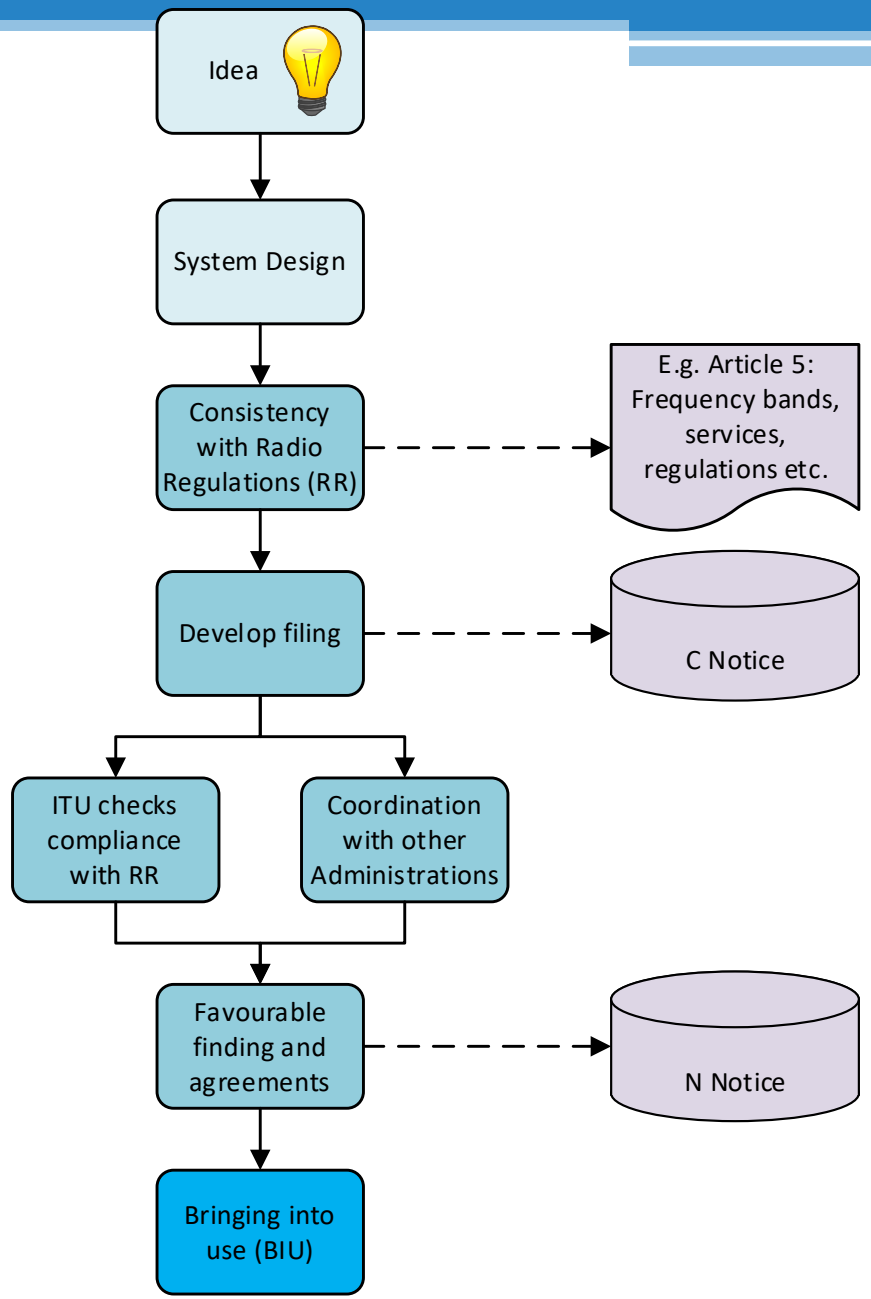
Thank you!



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