Earth Observation Missions and UWB Technologies: a risk analysis for spaceborne passive remote sensing in Europe

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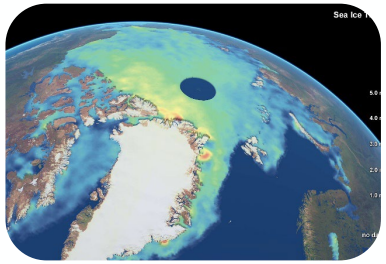
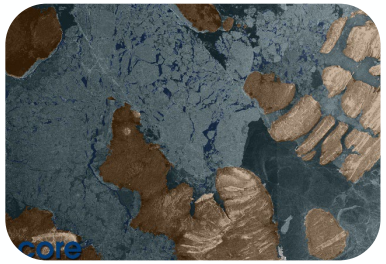
Spaceborne passive remote sensing of the Earth:
definition and mission objectives

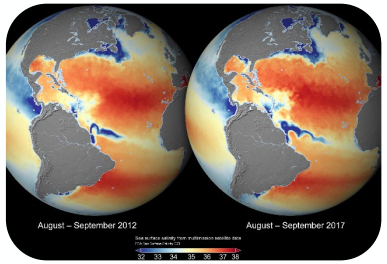
- All-weather **surface** and **atmospheric** profiles measurement and imagery of **natural** electromagnetic radiation, emitted and reflected by the Earth, enabling unique **measurements** of:



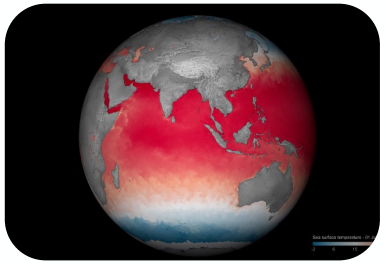
Sea ice concentration, thickness and drift



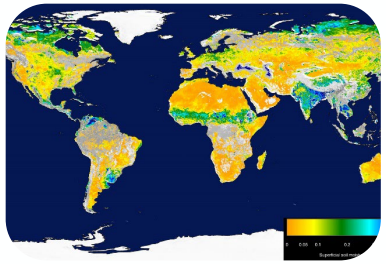
Ice type and development stage



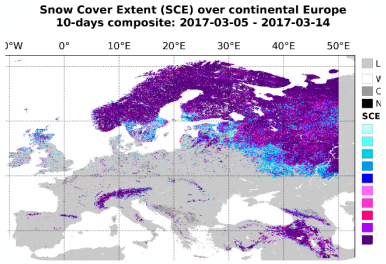
Ocean and ice salinity



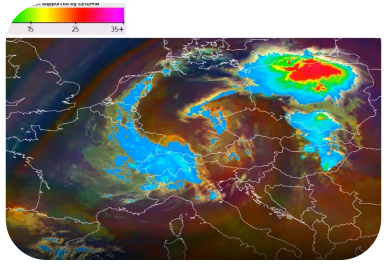
Land, sea and ice surface temperature



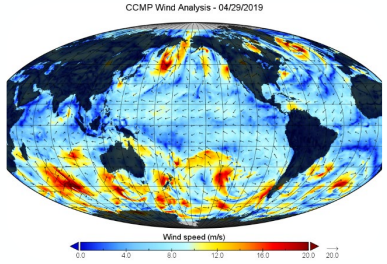
Soil Moisture



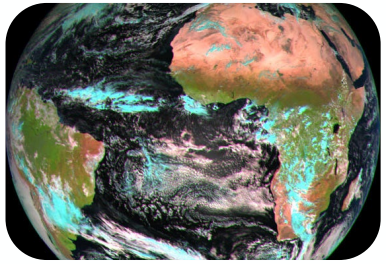
Snow cover (area and water equivalent) and snow depth



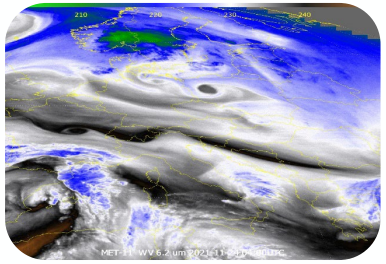
Precipitation (rain rate)



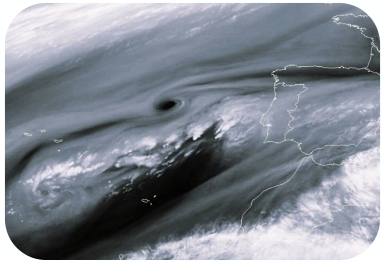
Wind speed



Ice cloud and hydrometeors characterization



Cloud liquid water vapor

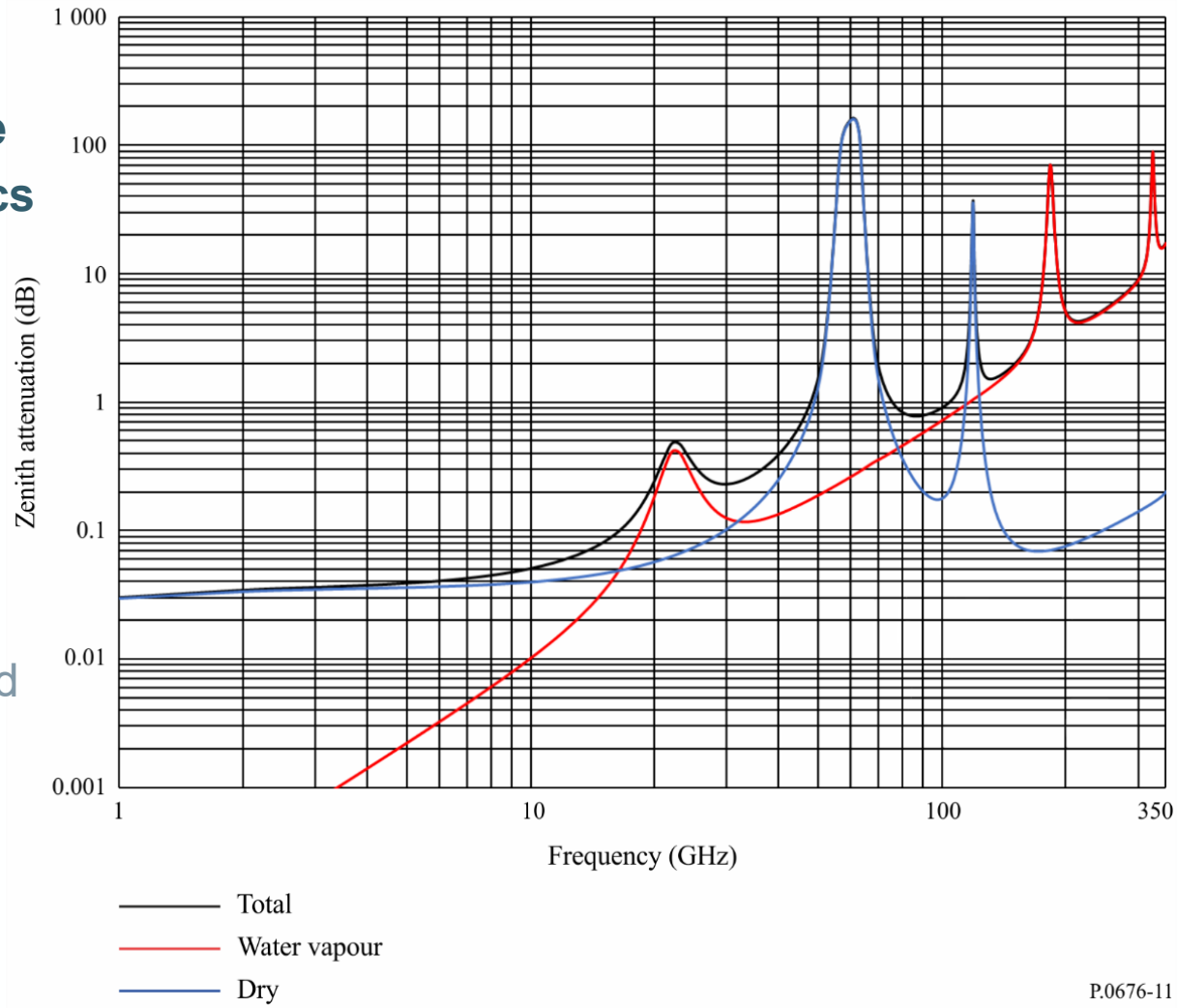


many more…

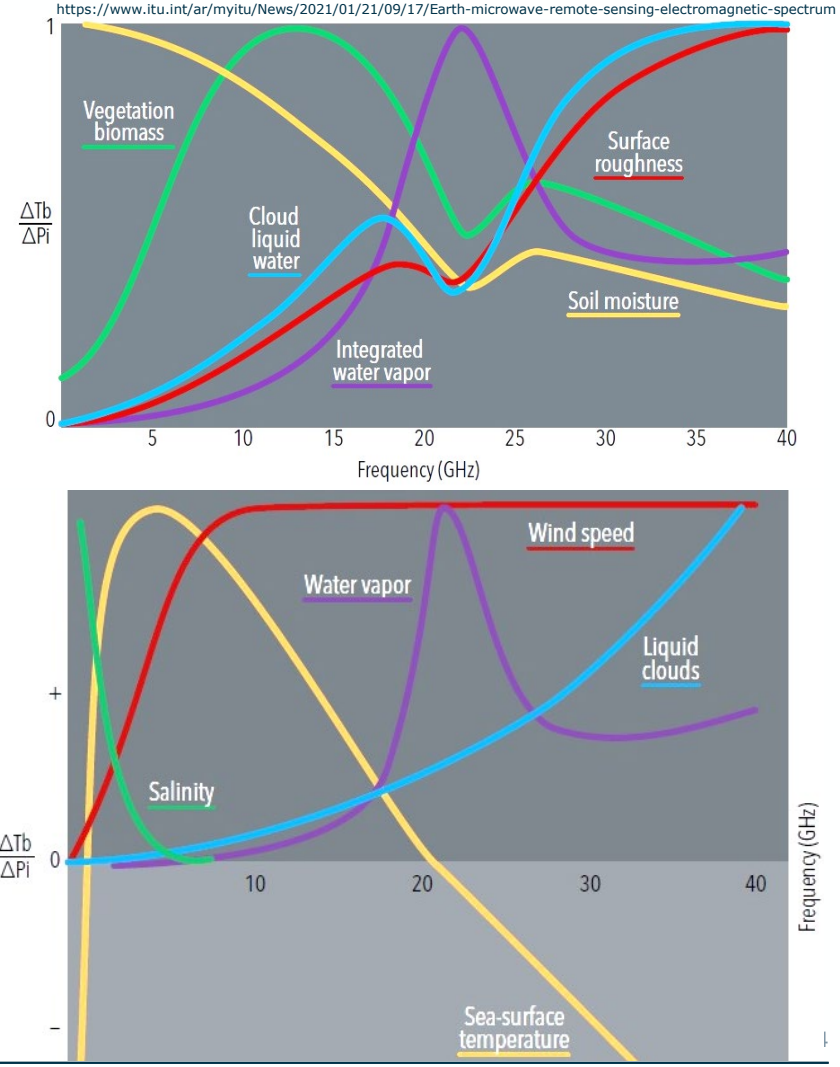
Spaceborne passive remote sensing of the Earth:
very specific radio spectrum requirements

- Centre-frequency naturally **defined by the laws of physics**
- Bandwidth driven by the mission performance requirements and conditioned by the satellite orbital parameters

Unique natural resources to preserve for sake of the future generations !



Credits: Paolo de Matthaeis
https://www.itu.int/ar/myitu/News/2021/01/21/09/17/Earth-microwave-remote-sensing-electromagnetic-spectrum



Spaceborne passive remote sensing of the Earth:
frequency allocations and regulatory framework

- Radio service designation: **Earth Exploration-Satellite Service (EESS) (passive)**

Regulatory Recognition

Primary Frequency Allocation			Secondary Frequency Allocation	Acknowledgement of spectrum use
Shared with passive services only	Shared with passive services only but with conditions	Shared with active services	Shared with active services	Shared with active services
RR No. 5.340 "all emissions are prohibited"	e.g. RR No. 5.340.1 "should not impose undue constraints on"	Coexistence conditions	Coexistence conditions	RR No. 5.458 "measurements are carried out (…), bear in mind the needs (of the service)"
Entitled to radioelectric protection	Entitled to radioelectric protection	Entitled to radioelectric protection	Entitled to radioelectric protection from secondary users brought into use at a later stage	No entitlement to international radioelectric protection

Recommendation ITU-R RS.515-5
(08/2012)

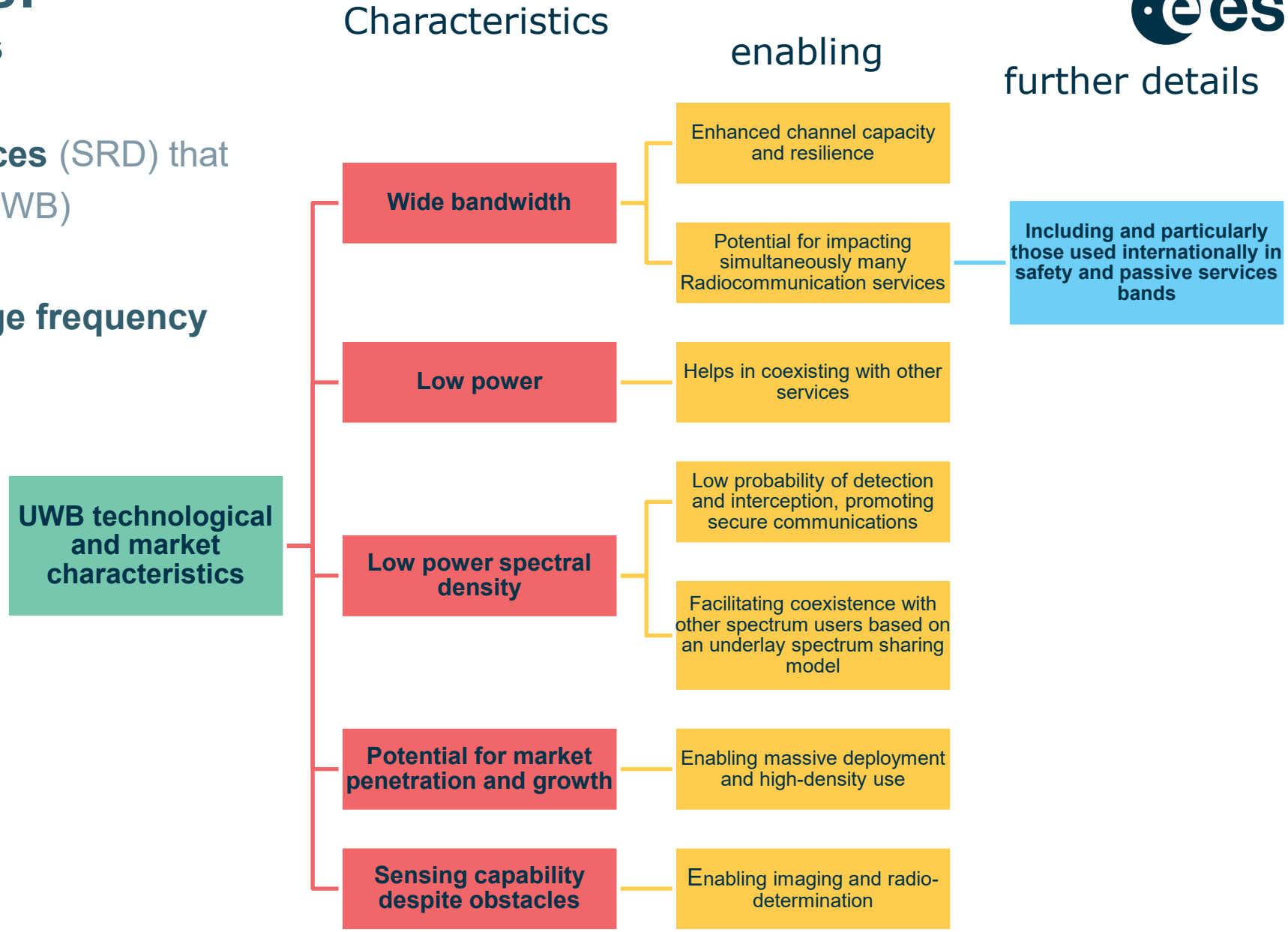
Frequency bands and bandwidths used for satellite passive remote sensing

1400.000 - 1427.000 MHz	86.000 - 92.000 GHz
2690.000 - 2700.000 MHz	100.000 - 102.000 GHz
10.600 - 10.680 GHz	109.500 - 111.800 GHz
10.680 - 10.700 GHz	114.250 - 116.000 GHz
15.350 - 15.400 GHz	116.000 - 120.020 GHz
18.600 - 18.800 GHz	120.020 - 122.250 GHz
21.200 - 21.400 GHz	148.500 - 151.500 GHz
22.210 - 22.500 GHz	155.500 - 158.500 GHz
23.600 - 24.000 GHz	164.000 - 167.000 GHz
31.300 - 31.500 GHz	174.800 - 182.000 GHz
31.500 - 31.800 GHz	182.000 - 185.000 GHz
36.000 - 37.000 GHz	185.000 - 190.000 GHz
50.200 - 50.400 GHz	190.000 - 191.800 GHz
52.600 - 54.250 GHz	200.000 - 209.000 GHz
54.250 - 55.780 GHz	226.000 - 231.500 GHz
55.780 - 58.200 GHz	235.000 - 238.000 GHz
58.200 - 59.000 GHz	250.000 - 252.000 GHz
59.000 - 59.300 GHz	

in *red*, RR No. 5.340 applies

UWB Technologies:
definition and charateristics

- A subset of **sort-range devices** (SRD) that use Ultra Wide Bandwidth (UWB) technology
  - **spread over a very large frequency range**



UWB Technologies:
frequency allocations and regulatory framework

- Radio service designation: none – **not recognized as** operating under allocations to **radio services** nor recognized as industrial, scientific and medical (ISM) applications
- **Regulatory regime for implementation of SRDs** (including frequency-bands, rights and conditions to operate, market access and certification) **is a matter for national administrations**
- National regimes for implementation are, in general, as simple as possible to minimize the burden on administrations and users of SRDs

Administrations authorizing or licensing devices using UWB technology **should ensure**, pursuant to the provisions of the Radio Regulations, **that these devices, will not cause interference to**, and will not claim protection from, or place constraints on, the **radiocommunication services of other administrations** as defined in the Radio Regulations and operating in accordance with those Regulations

Upon receipt of a notice of interference to the radio services from devices using UWB technology, **administrations should take immediate action(s) to eliminate such interference**

Recommendation ITU-R SM.1896-1
(09/2018)

Frequency ranges for global or regional harmonization of short-range devices

9.0 – 148.5 kHz	3.1 – 10.6 GHz
3155 – 3400 kHz	5725 – 5875 MHz*
6765 – 6795 kHz*	24.0 – 24.25 GHz*
13.553 – 13.567 MHz*	61.0 – 61.5 GHz*
26.957 – 27.283 MHz*	122-123 GHz*
40.66 – 40.70 MHz*	244 – 246 GHz*
2400 – 2500 MHz	...

Designated ISM band marked with *asterisk (*)*

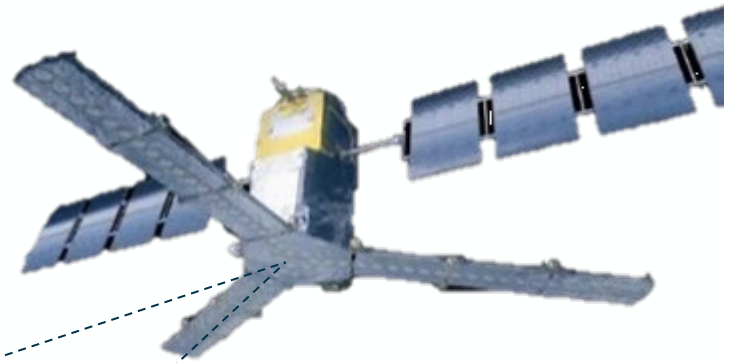
Bands relevant for EESS(passive) coloured in *red*

ITU-R SM.1756

Spectrum sharing and coexistence scenario

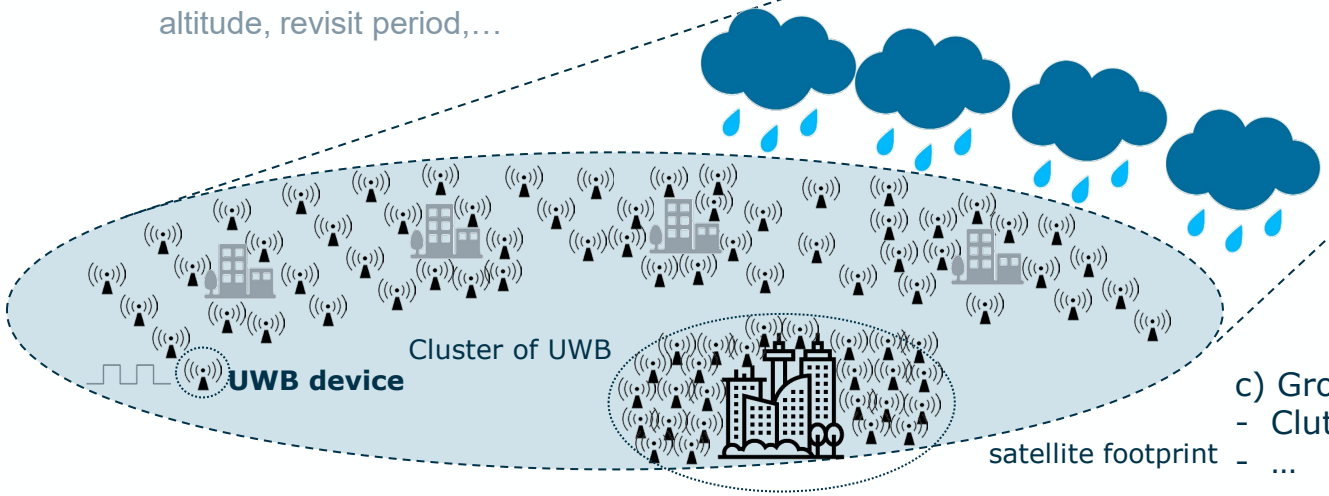
Some **aspects influencing the coexistence scenario**:

- In-force regulatory framework and spectrum use
  - apportionment of the maximum allowable interference level between spectrum users (at different levels)
- UWB technical characteristics
  - Tx power, antenna gain, spectrum requirements,…
- UWB operational modes and deployment model
  - elevation angle, activity factor, density and market dynamics of competing technologies,…
- Radiowave propagation effects
  - on ground and in the atmosphere
- EO sensor characteristics and operational parameters
  - sensitivity, antenna gain, protection level requirements,…
- Mission orbital parameters
  - altitude, revisit period,…



Affected satellite
- Integrating the power of all UWB devices deployed in its footprint

Difficulties coming from?



a) Ionospheric effects on radiowave propagation
- Scintillation
- Faraday's rotation
- …

b) Tropospheric effects on radiowave propagation
- Scintillation
- Attenuation
- Depolarization
- …

c) Ground effects on radiowave propagation
- Clutter
- …

Governance policy and practices:
spectrum planning

Coexistence between **passive remote sensing and UWB technologies: a spectrum planning issue? Not necessarily!**

- **Frequency-bands under RR No. 5.340** and used by passive remote sensing **are equivalent to natural reserves**:
  - They cannot be replaced, even if more spectrum is to be provided for that application in another frequency-band, because the features to be measured can only be measured in that frequency-range so defined by nature
  - For their unique properties and leveraged applications, they require unique protection

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https://www.deutschland.de/en/topic/environment/unesco-biosphere-reserves-in-germany-and-worldwide

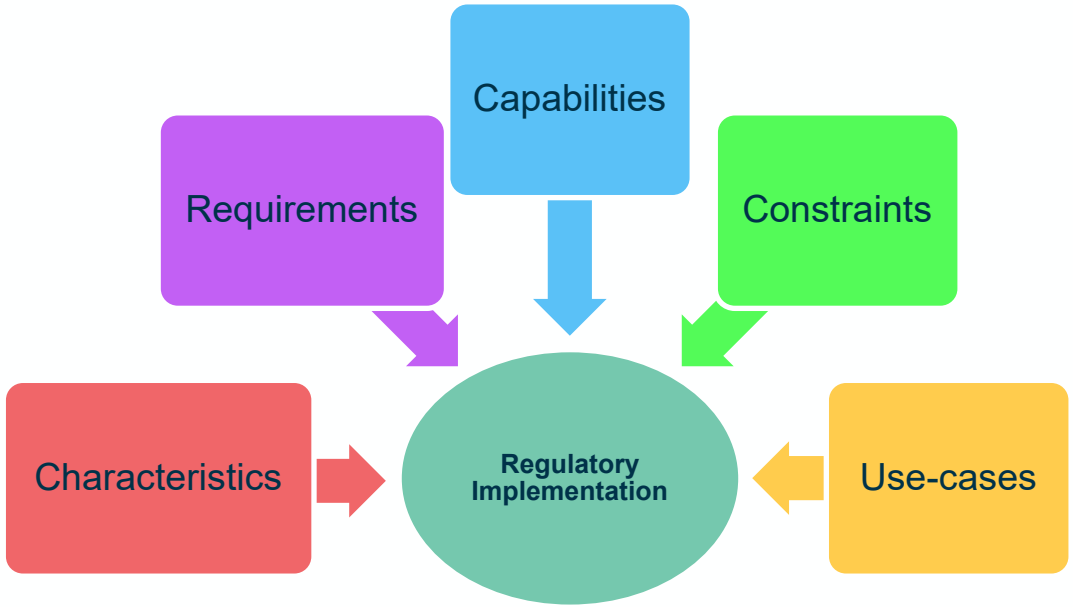
Acknowledge the need for unique protection of these very special radio spectrum resources
Refrain from considering using them for purposes that can be served by other resources

Governance policy and practices:
regulatory instruments and implementations

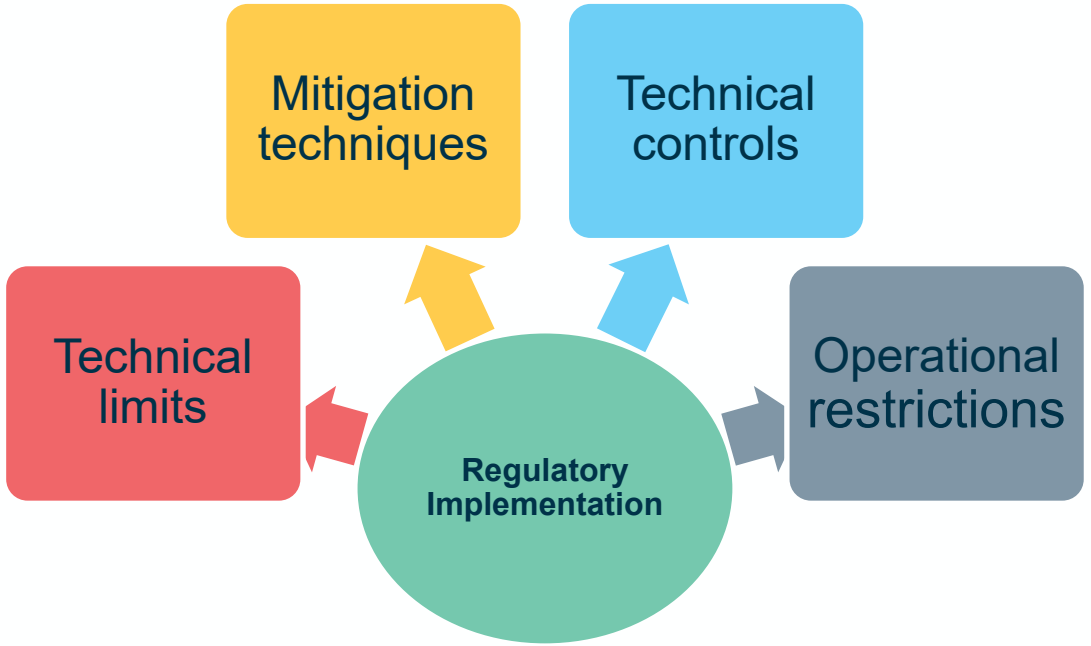
Coexistence between **passive remote sensing** and **UWB technologies:**
a regulatory issue? Not necessarily!

Technical and operational features,

- for each type of UWB application,
- for all potentially affected radio services



Regulatory implementation includes



Ensure spectrum engineering studies are realistic
Ensure regulatory implementation is enforceable, based on objective and measurable criteria

Governance policy and practices:

market access conditions, radio stations licensing or registration regime

Coexistence between **passive remote sensing and UWB technologies: a spectrum licensing issue? Not necessarily!**

Licensing is an appropriate tool for administrations to regulate the use of radio equipment and the efficient use of the frequency spectrum

Accept burden in licensing UWB devices sharing the spectrum with EESS(passive) (e.g. in the form of a light-licensing regime with limitations in the number of users) for sake of effective deployment and market penetration control

SRDs are generally exempted from individual licensing

Individual license

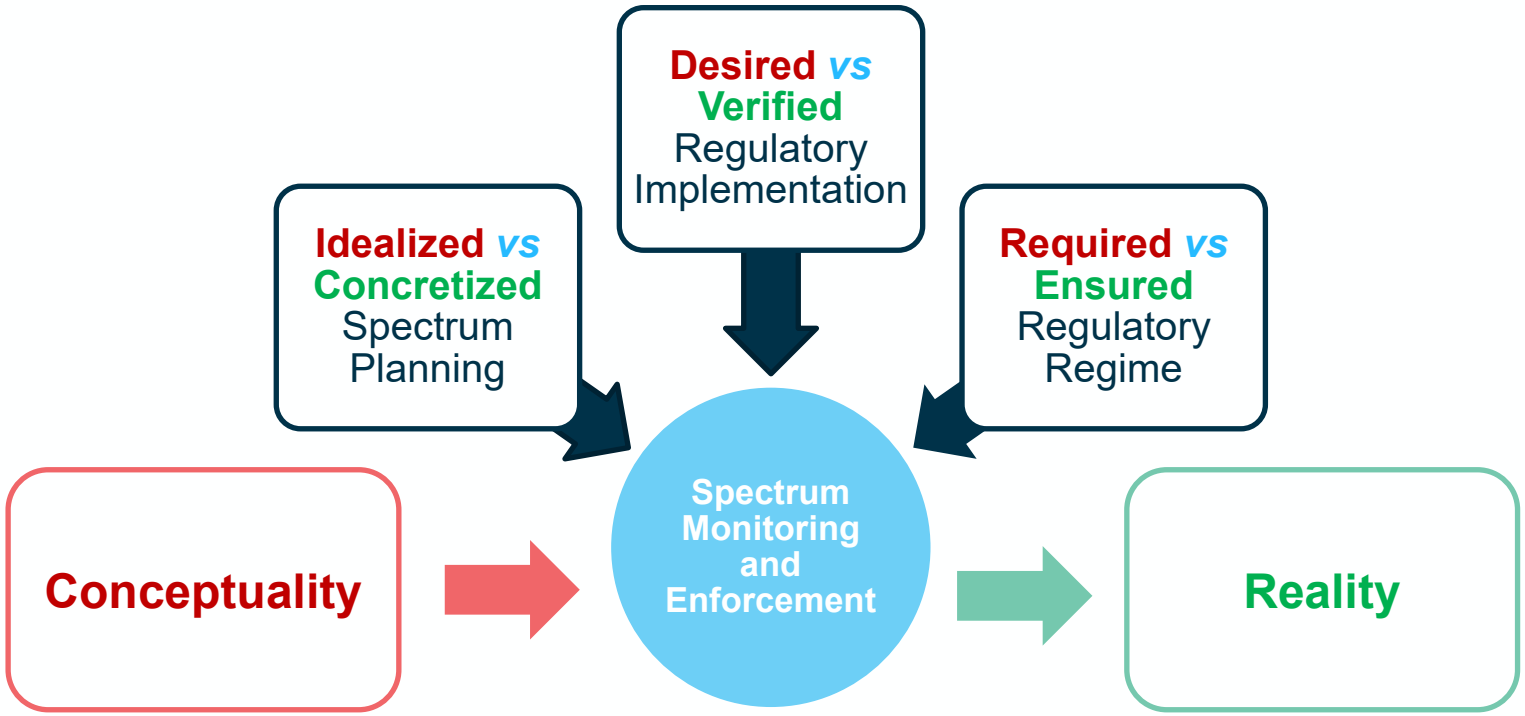
Light-licensing

License-exempt

Governance policy and practices:

Spectrum monitoring, technical and regulatory enforceability and RFI management

Coexistence between **passive remote sensing and UWB technologies:**
a spectrum control issue? Not necessarily!

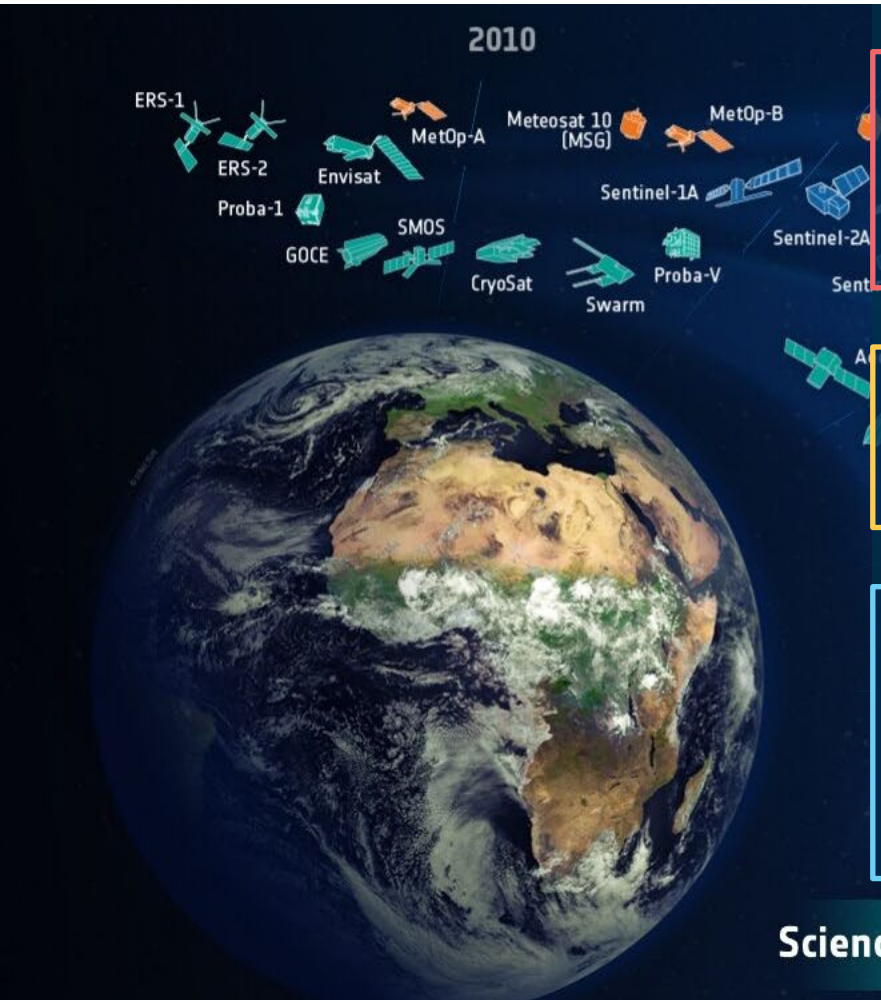


Carry-out preventive spectrum monitoring practices to ensure the spectrum sharing conditions are as planned
Monitor the deployment of UWB devices and control interference level
Execute inspection actions on UWB devices to ensure conformity with regulatory regime in using the spectrum
React promptly upon receiving interference report and mitigate the interference

Roles of frequency management for EO missions:

applicable to the whole range of EO Missions

Coexistence between **passive remote sensing and UWB technologies:**
it is an EO mission issue!



Spectrum Planning

- **Ensure full compliance with the in-force ITU-R Radio Regulations** and Recommendations
  - Take actions towards the change of the regulations, if needed

Spectrum Licensing

- Coordinate the mission, notify the satellite and **secure international recognition and protection with the ITU**

Spectrum Monitoring and Enforcement

- **Detect and report all instances of *harmful* interference**
  - **What is not reported, never happened**
- Coordinate interference mitigation operations with national authorities
- Flag and/or discard interfered data

Science esa Copernicus Meteorology EUMETSAT

Mitigation techniques for UWB technologies

Coexistence between **passive remote sensing and UWB technologies: a UWB issue? Not necessarily!**

- Various **mitigation techniques** can be used **to reduce the impact of UWB devices on Radio services**
- Not all technological implementations are effective for the coexistence with passive services

Spectral control techniques of UWB emissions
- To smooth or to lower the PSD in certain frequency-bands

Cross-polarization
- To get additional isolation between interferer system and interfered victim

Notch filtering
- To suppress certain spectral contents
- Impairs the application performance

UWB modulation and channelization schemes
- To shape the PSD

Frequency hopping
- To reduce and/or suppress emission to certain frequency-bands
- Namely by disabling the hopping to the corresponding frequency-band

Chirp signaling
- To reduce emission to the victim frequency-band by continuously changing the frequency of the UWB pulse

Frequency agile modulation
- To allow for an emission level definition according to the actual requirements at each portion of the UWB spectrum

Spatial radiation control techniques
- To control antenna radiation properties, including pattern and directivity

Detect and avoid technology
- To detect the presence of the victim and reduce transmitted power to avoid interference

...

Notch out frequency-bands subject to RR No. 5.340
For other bands, accept that a compromise in sharing the spectrum is mandatory for sake of coexistence

Take home messages:

Balanced governance for efficient, effective and improved coexistence

Everyone desires more bandwidth

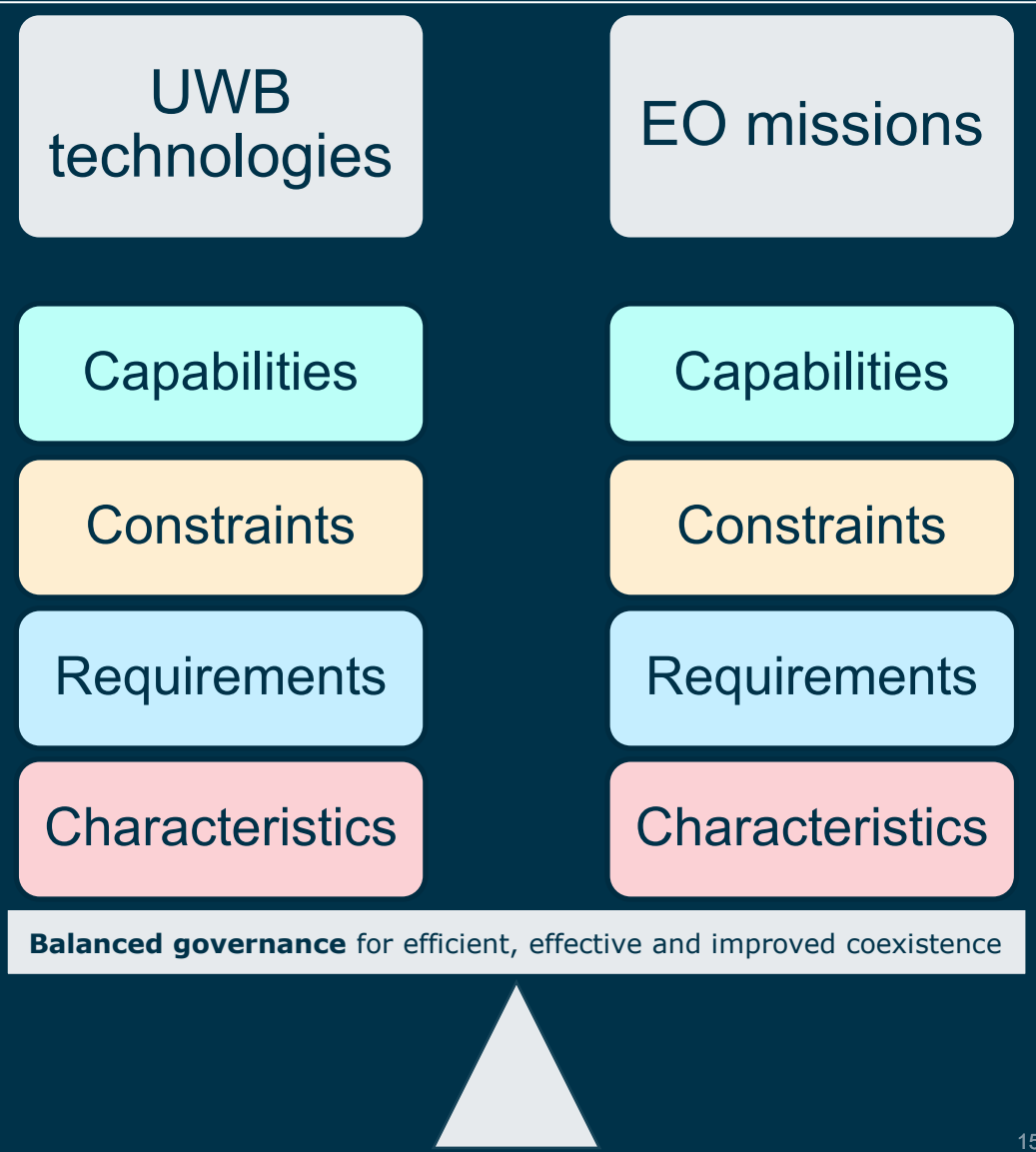
Coexistence means that a compromise is mandatory

Everyone must work together for an effective and efficient use of the scarce radio spectrum resources:

- Governments and national authorities
- UWB manufacturers and users
- EO systems manufacturers and operators

Some guiding principles for the introduction of UWB technologies:

- UWB devices shall not impact stations of other administrations
  - EESS(passive) is a global service and EO missions are, in general, stations of other administrations
- Special attention should be given to difficult scenarios that may arise as a result of the aggregate effect of the deployment of UWB devices and to provide the required protection to services operating in the frequency bands listed in RR No. 5.340



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