GEO, MEO and LEO satellites for railway sector

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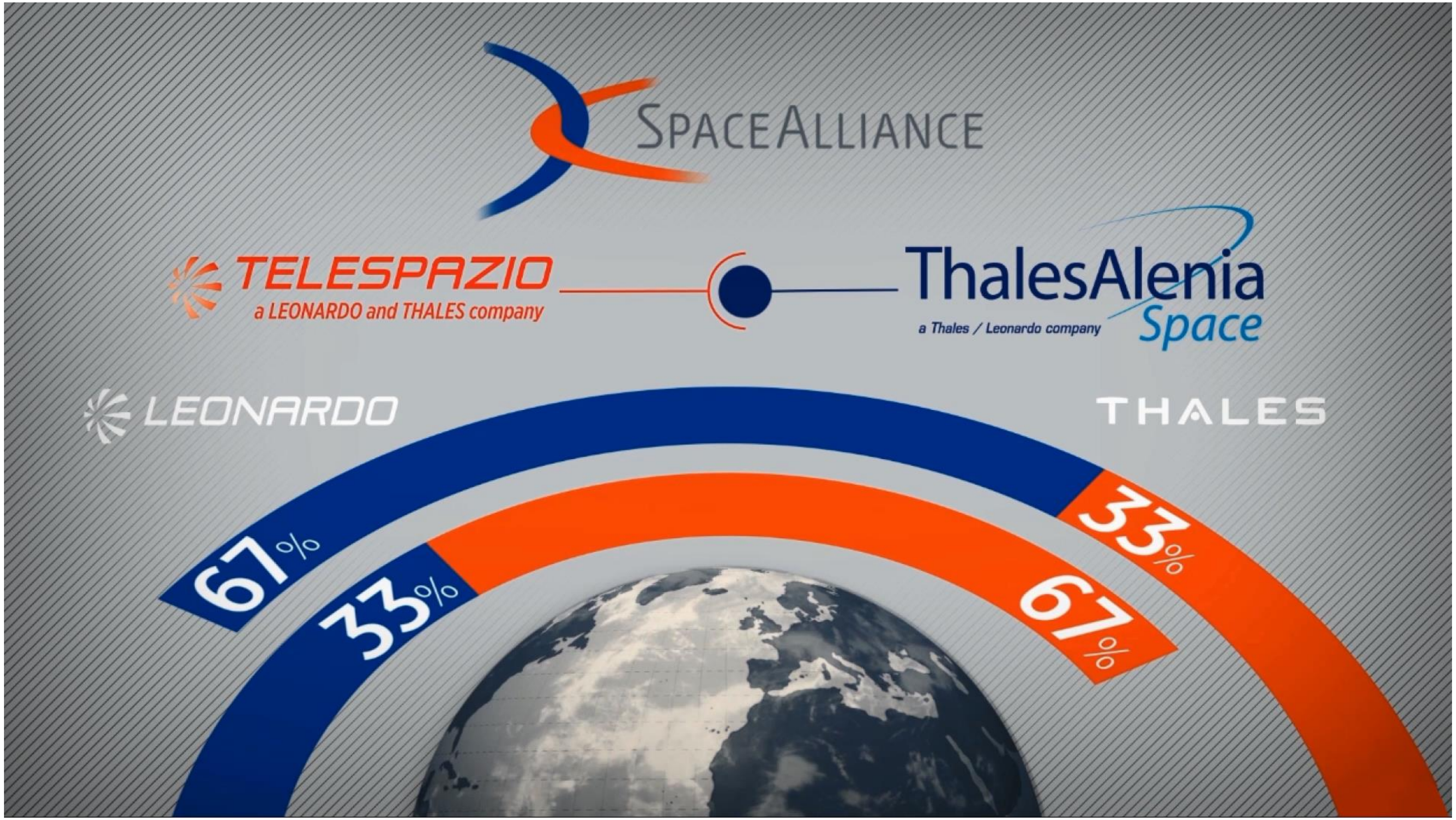
TELESPAZIO

Telespazio, a joint venture between Leonardo (67%) and Thales (33%), is one of the world's leading players in satellite services. The company, headquartered in Rome (Italy), employs approximately 2500 people.



SPACE ALLIANCE: TELESPAZIO AND THALES ALENIA SPACE

FRMCS and Bearer solutions

- Railway community is working on standardizing the **Future Railway Mobile Communication System (FRMCS)**, the successor of GSM-R that will to support new railway functionalities
- **5G is the target technology** for FRMCS. It is expected to provide a low-latency and spectrally efficient solution which will be a key enabler for critical applications. Amongst others it is expected to grant:
  - Prioritized emergency group communication, train control data and video service
  - Seamless connectivity in high speed railway moving environments
  - Low latency and high reliable data and video service
  - Real time train monitoring and management for safe train operation
  - Reliable location tracking including tunnel condition
  - Legacy railway communication interworking to GSM-R system

- FRMCS is anyway designed on purpose in order to provide "**bearer flexibility**" in a way that is fully transparent to the applications such as ETCS, voice, ATO, etc.

- Therefore, **other communication solutions** that may be considered include:
  - other 3GPP transport technologies such as 4G
  - non-3GPP transport technologies such as **satellite connectivity** or Wi-Fi,
  - IP Private Radio Network

Multibearer communication concept

With GSM-R, railway-specific functionality is directly integrated into the technical specification of the transmission technology. **Separating the bearer** (the technical transmission technology aspects) **from the application** (railway functionality elements) allows a more flexible approach needed for the future. This separation is the essence of bearer independence

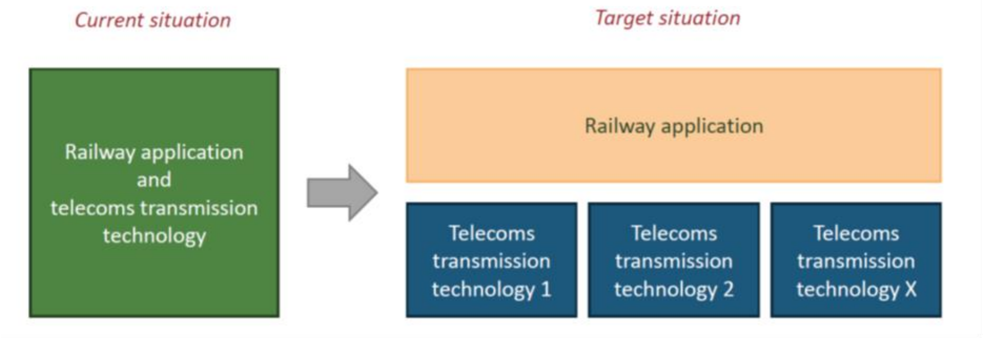
Bearer is a Digital Telecommunication Technology Standard based on:

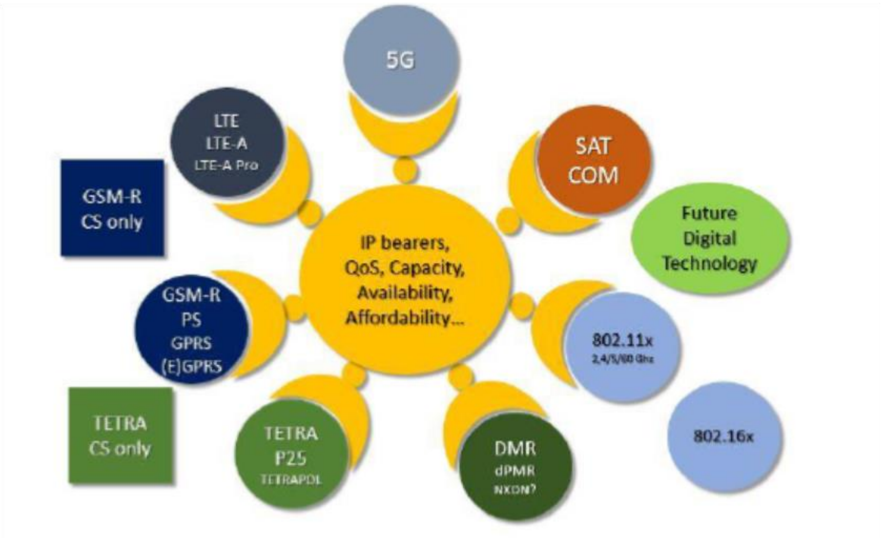
- **Open standards**
- **Terrestrial** (wireless and wireline) **and satellite technologies**: existing, emerging, and future standards
- **Circuit-switched** and **packet-switched** technologies.

However, the definition of a bearer is much more than a digital technology standard: we need to describe the **services** to be supported, the **protocols**, the **interfaces**, the **performance**, the **spectrum bands** and **access schemes**, and the **network models**. A single bearer could match:

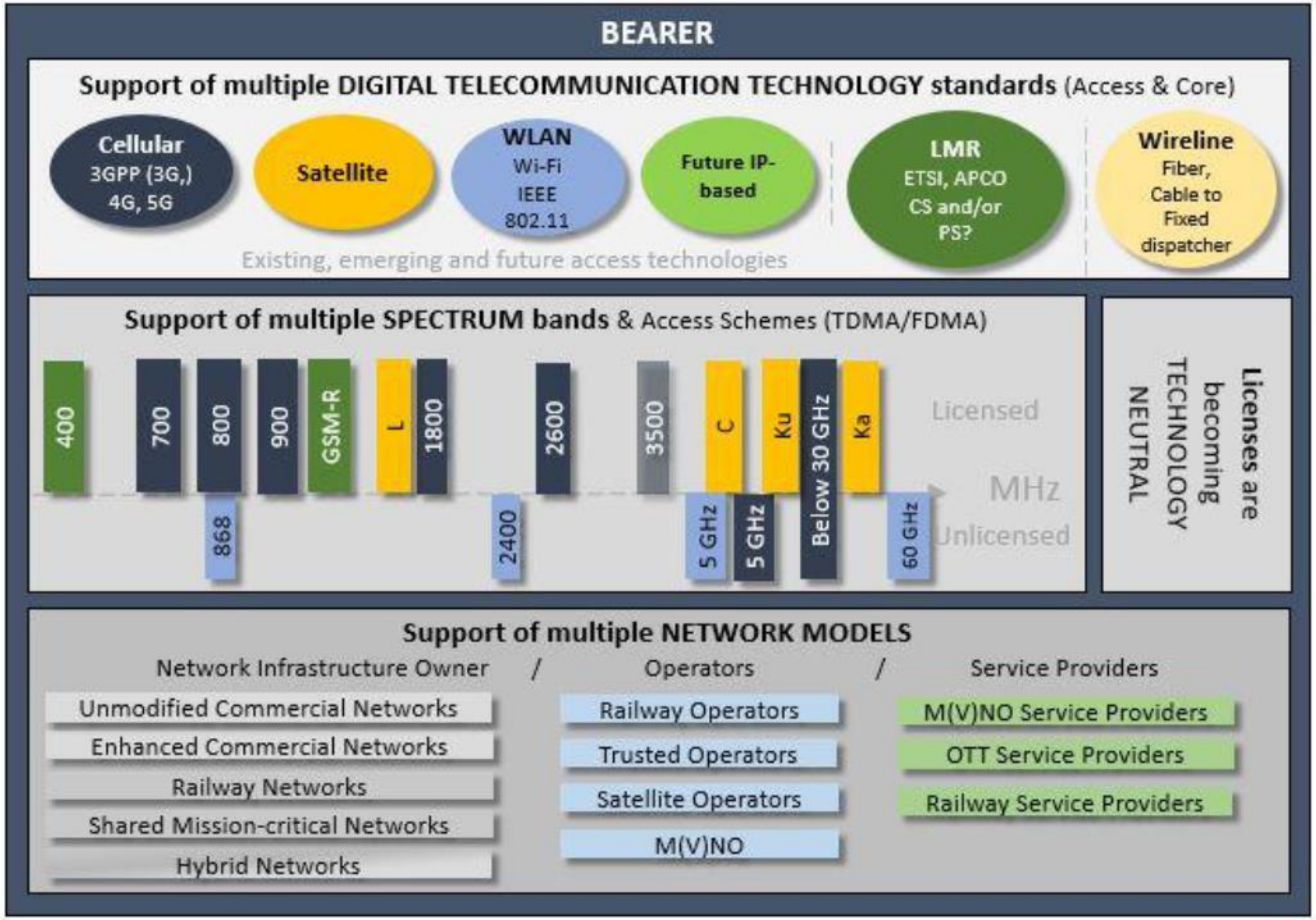
- Different bands and access schemes (Time-Division or Frequency-division multiple access including TDD/FDD, multiplexing & coding schemes techniques)
- Different spectrum access schemes (licensed, unlicensed or combined)
- Different network ownerships and controls
- But a single Radio Access Technology (RAT) and Core Network based on either circuit-switched or packet- switched mode

To define a specific bearer, **all these characteristics need to be considered**.

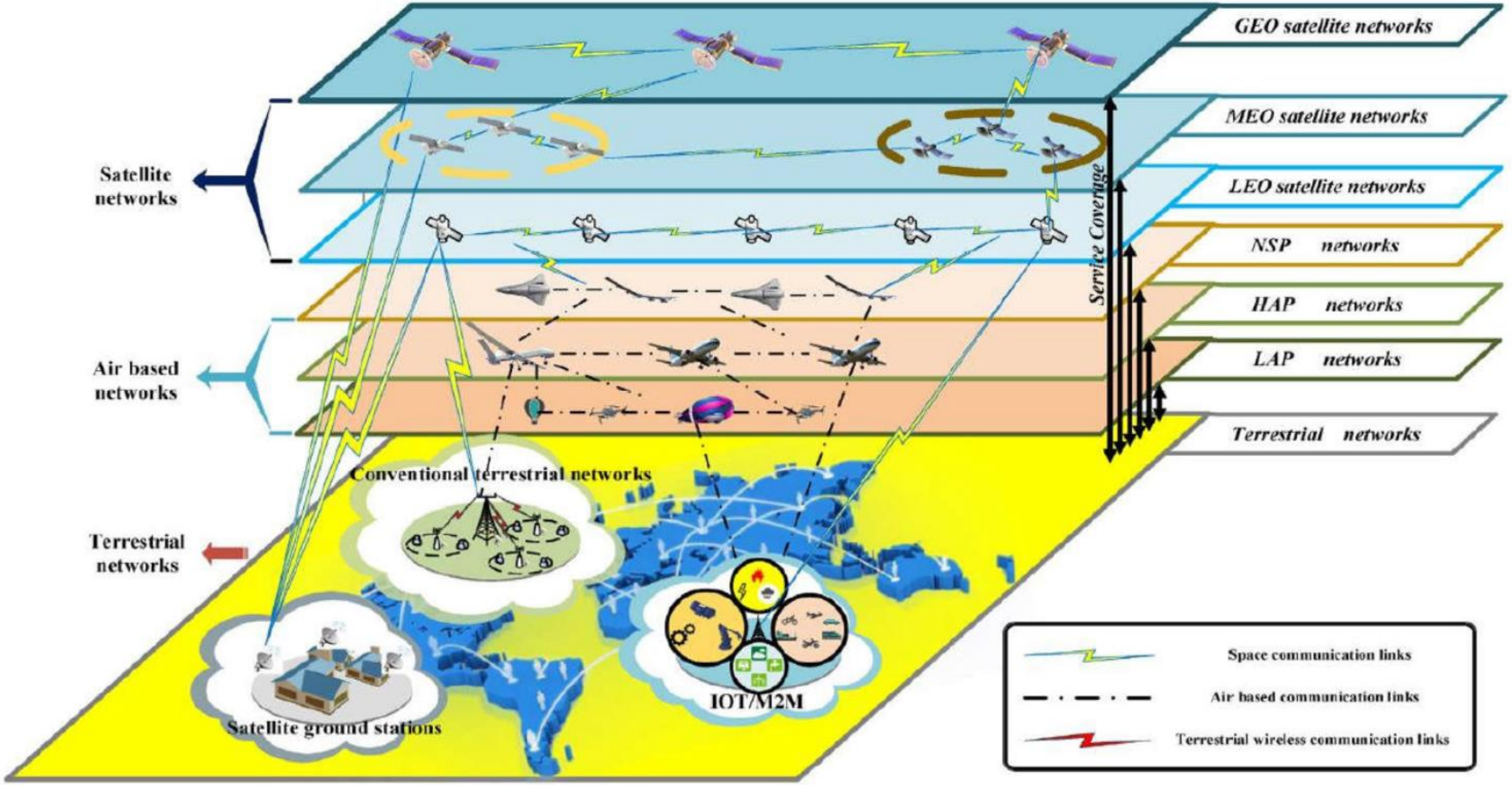




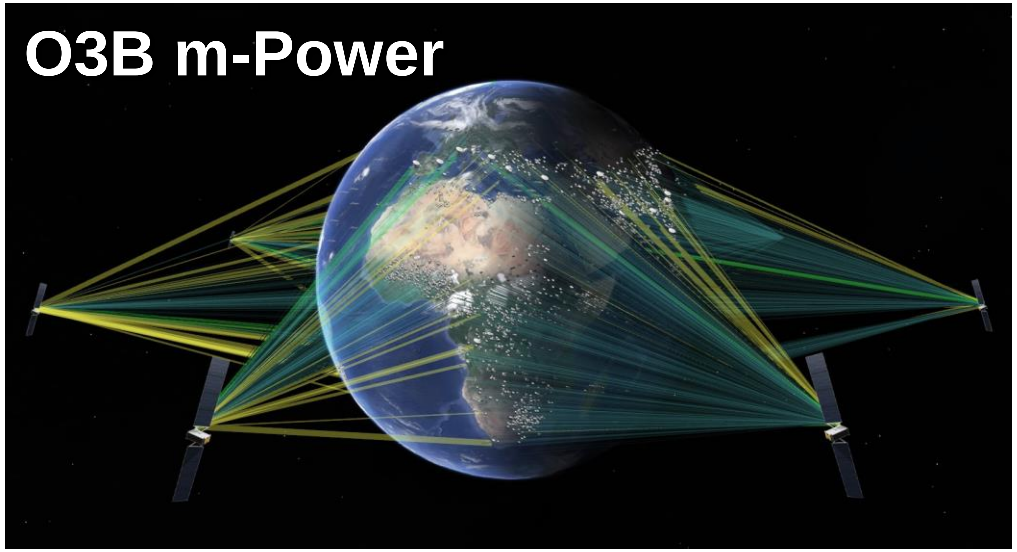
Overview of possible bearers

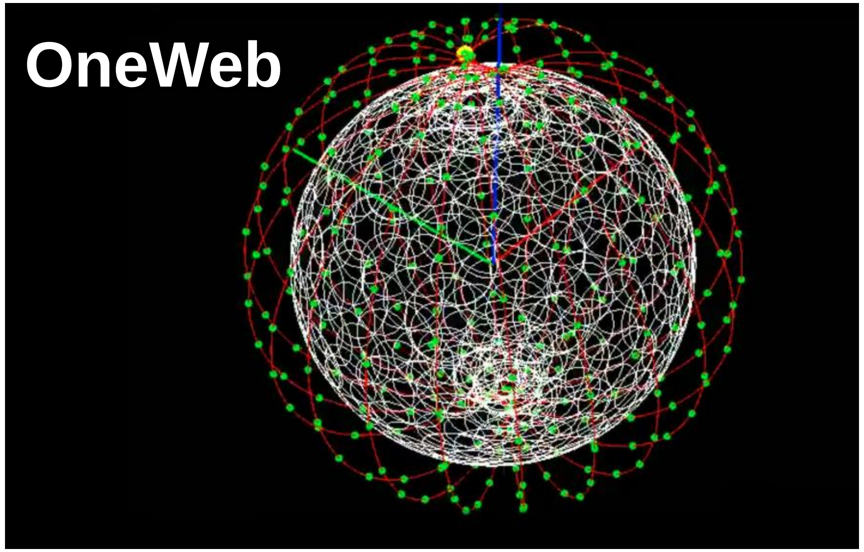


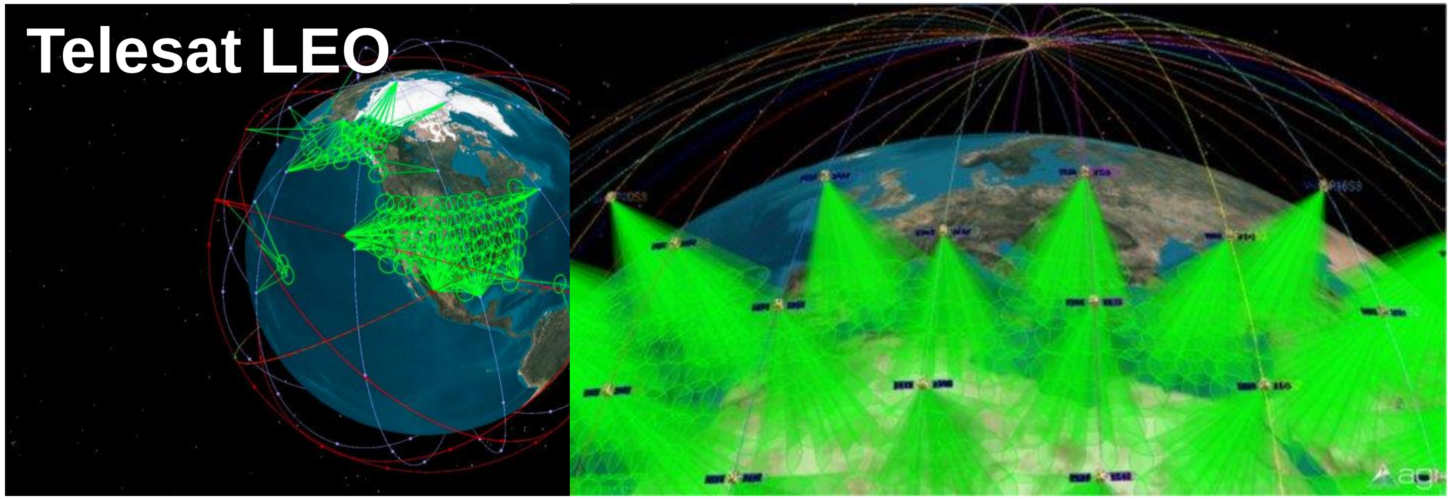
Wireless bearers

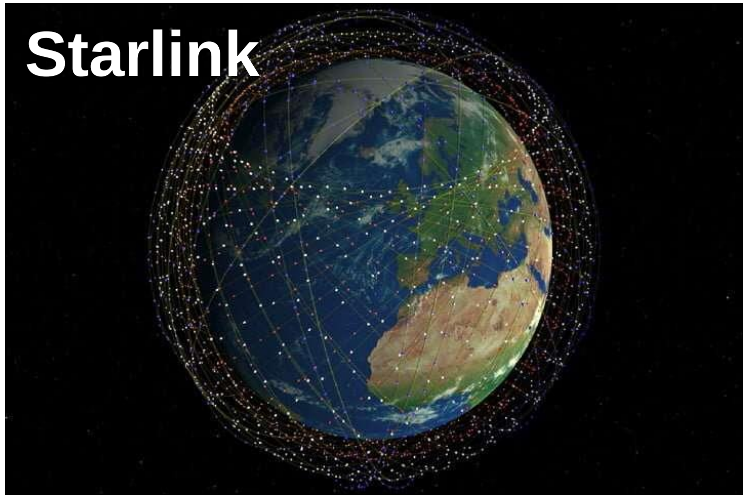


MEO and LEO CONSTELLATIONS







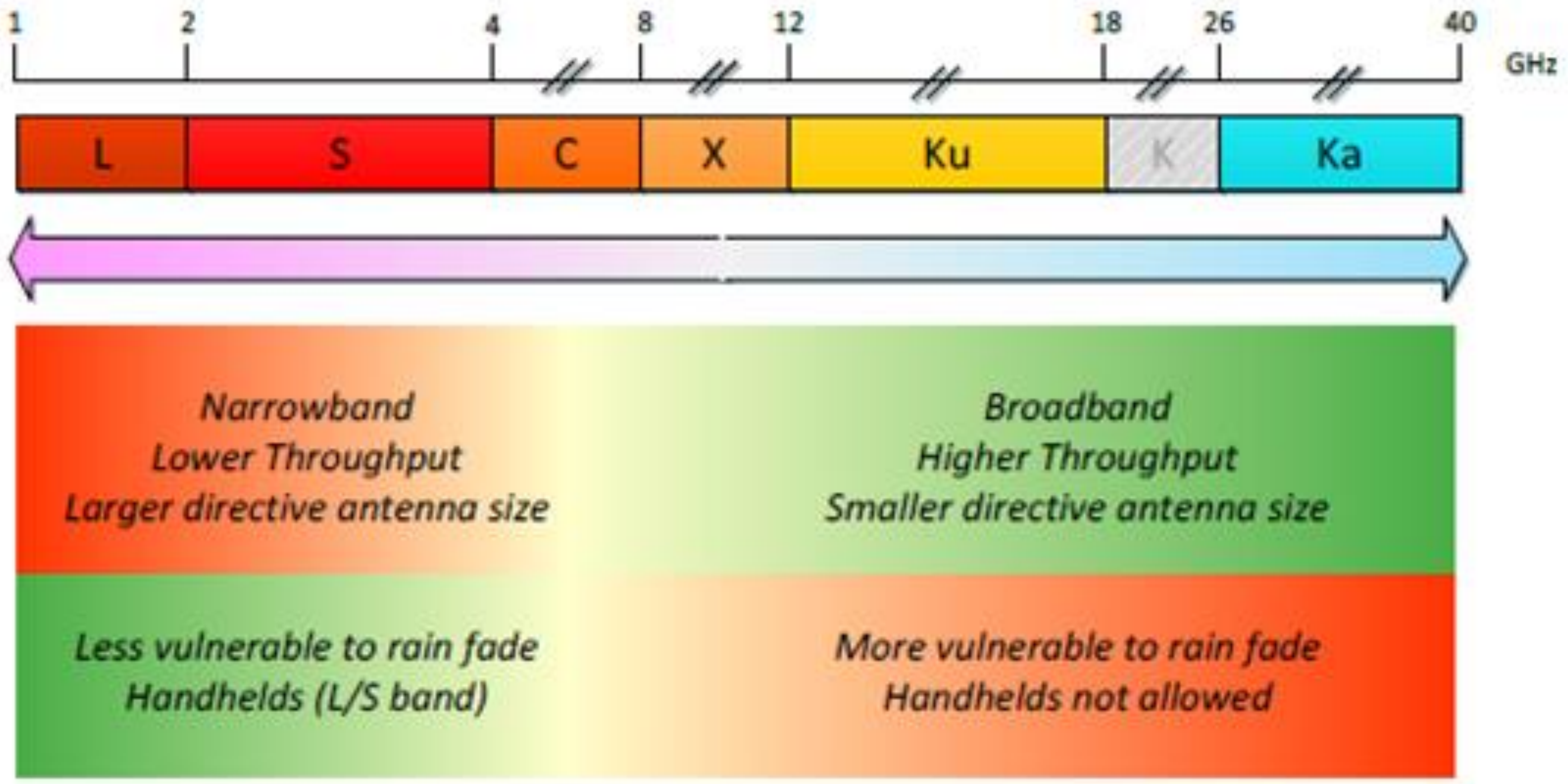


SATCOM bearer for FRMCS services

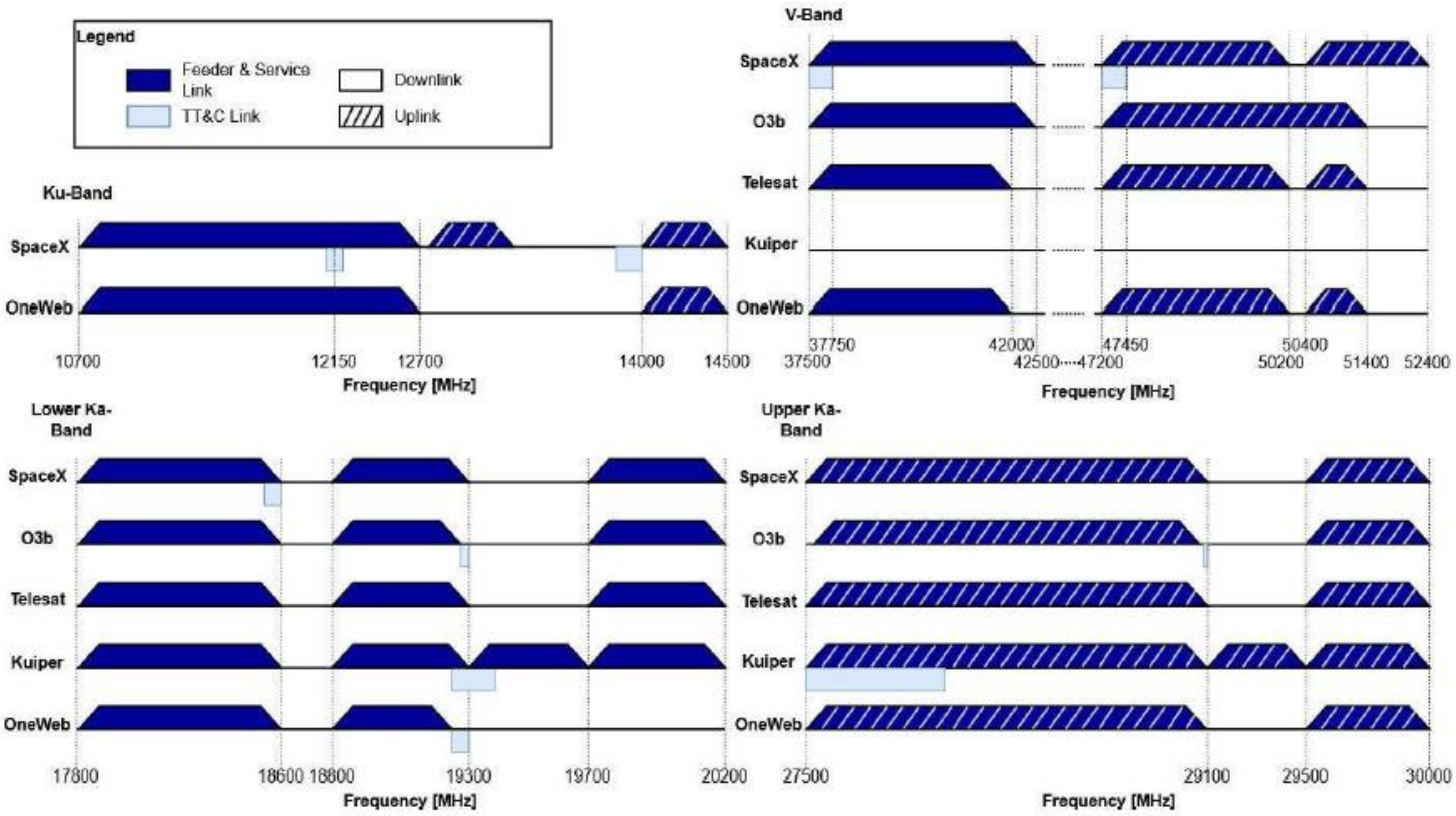
- Main conclusions derived from FRMCS specification of critical application are:
  - **High reliability** is required for critical applications (in comparison to the performance and business ones).
  - **Low latency** and immediate setup are highly demanded in most of the critical applications.
  - **Voice calls shall be support**, including train-to-OCC and multi-train.
  - **Narrow-band systems** seem to be sufficient to support voice and data in critical applications.
  - **Two-way communications** (i.e. 50/50 symmetry) are required for most of the critical applications.

- Some benchmark criteria for satellite solutions:
  - **Frequency band**. It impacts on **bandwidth availability** or **atmospheric signal degradation**, which depend directly on the frequency band selected. Higher frequency bands give access to broader bandwidths. However, they are also more susceptible to signal degradation due to rain fade (the absorption of radio signals by atmospheric rain, snow or ice).
  - **Satellite orbit**: It impacts on **propagation delay**, use of some **terminals types** (e.g. handheld), compliance of certain types of **antennas and satcom modem technologies** (due to operative maximum speed versus coverage, etc…).

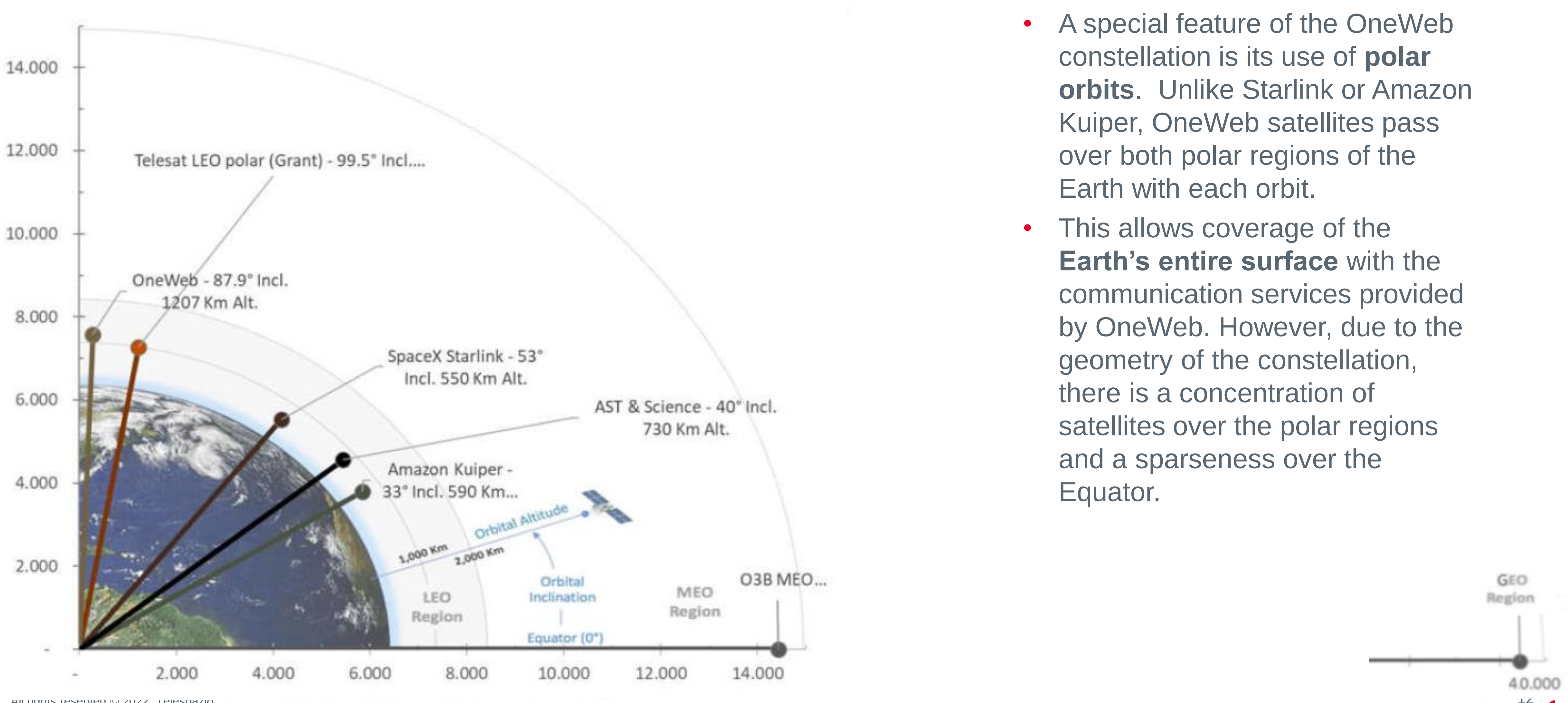
Major frequency band impacts



Overview of Frequency Usage for MegaConstellations



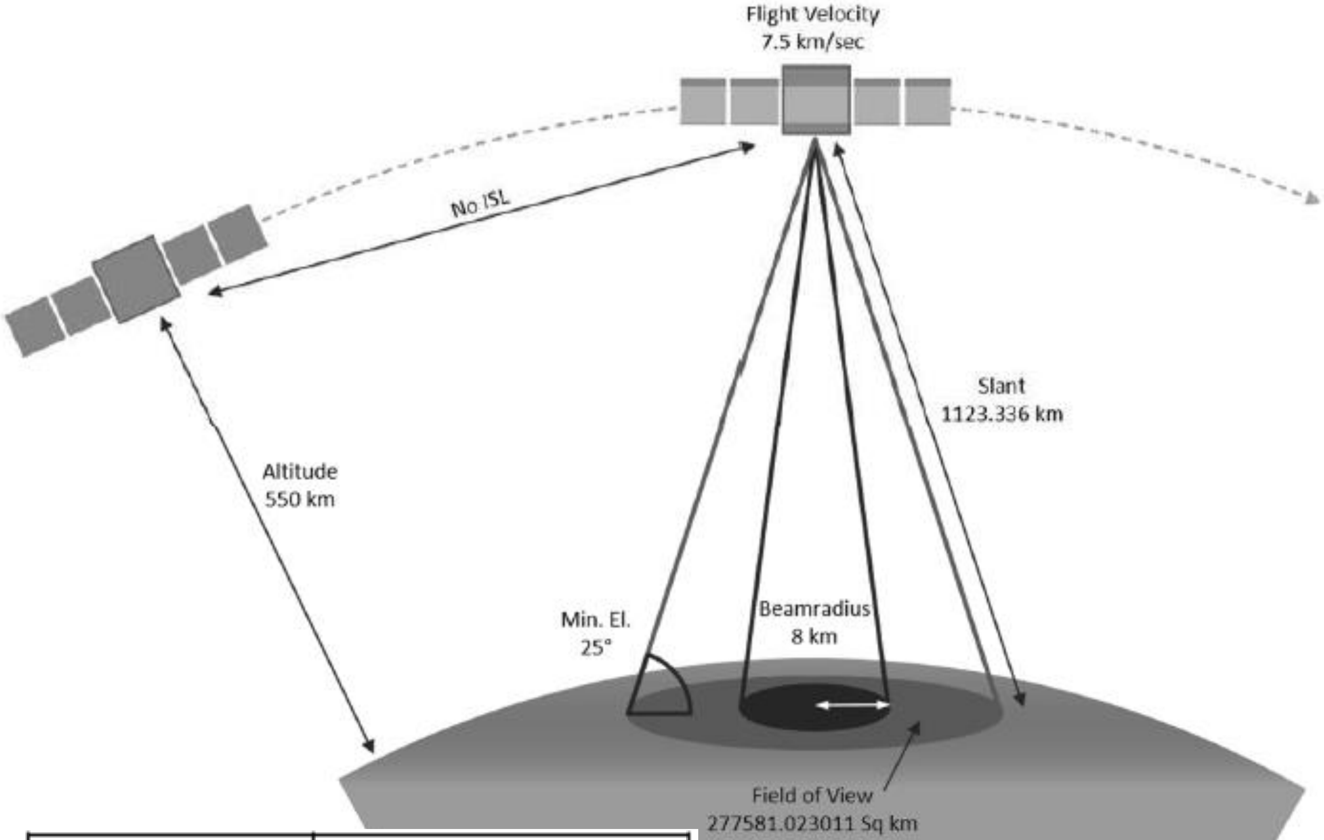
Example of a shell for some constellations, indicating altitude and inclination



- A special feature of the OneWeb constellation is its use of **polar orbits**. Unlike Starlink or Amazon Kuiper, OneWeb satellites pass over both polar regions of the Earth with each orbit.
- This allows coverage of the **Earth's entire surface** with the communication services provided by OneWeb. However, due to the geometry of the constellation, there is a concentration of satellites over the polar regions and a sparseness over the Equator.

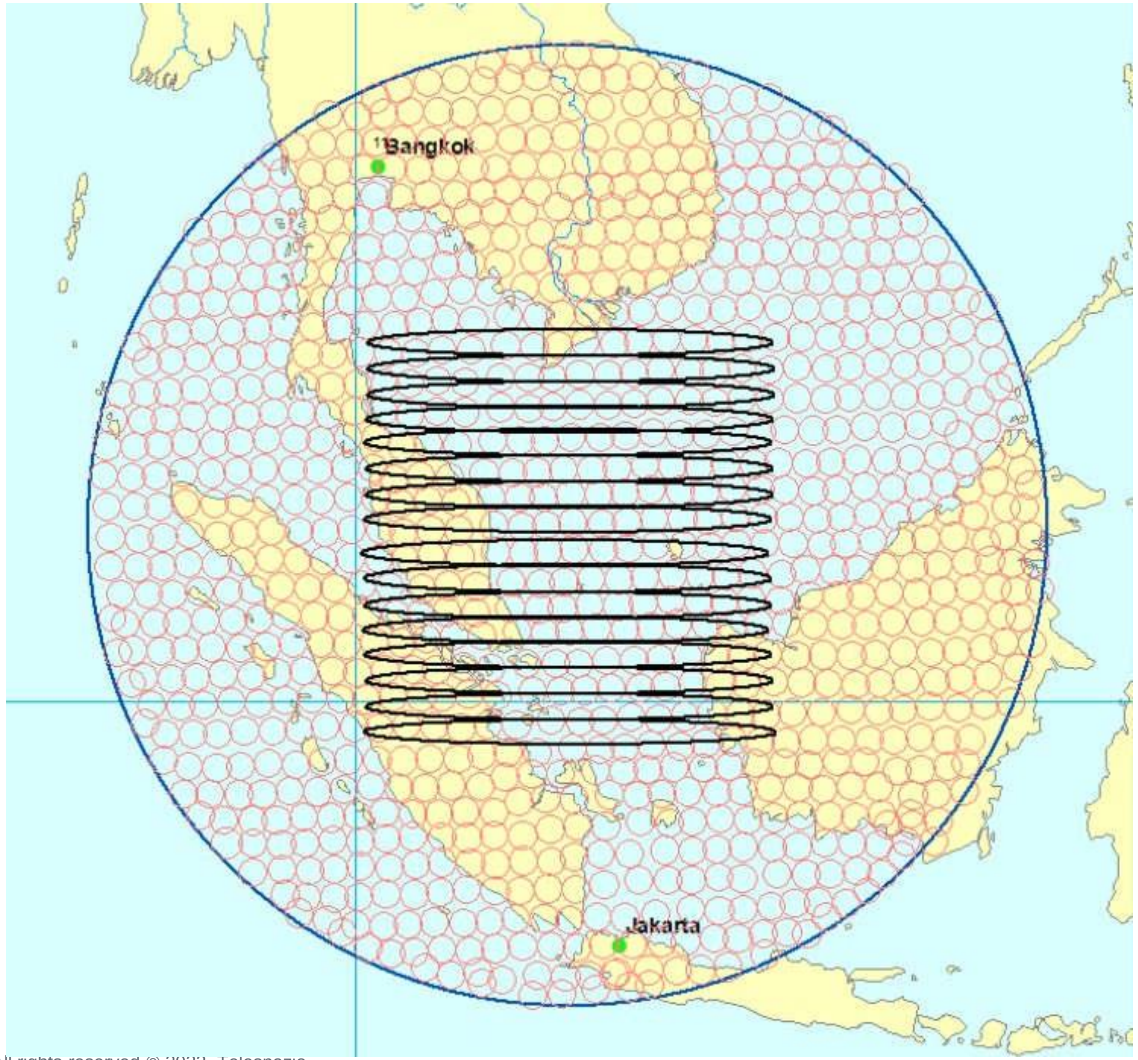
Starlink Satellite Flight and Associated Parameters

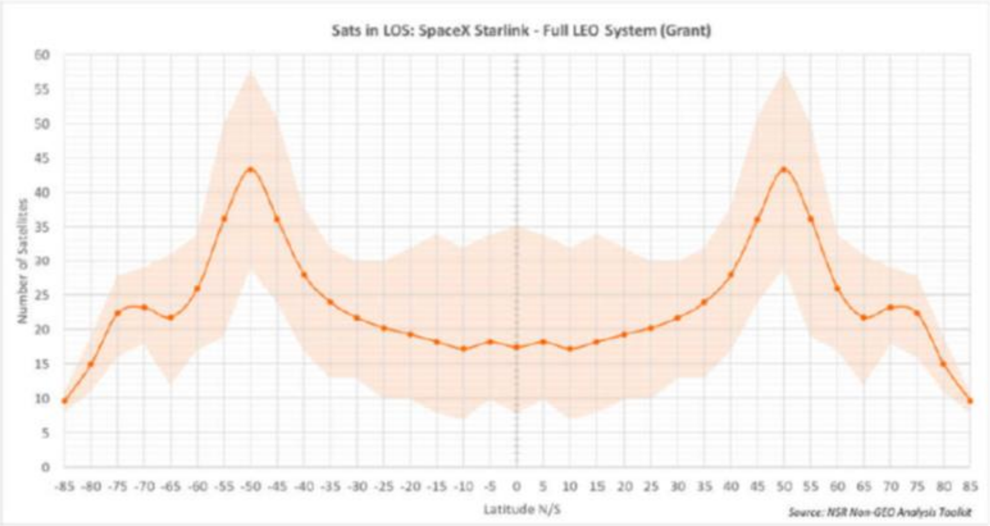
- A shell of the SpaceX Starlink constellation is shown in the figure with the parameters necessary for characterisation.
- An orbital shell comprises several satellites on one plane and is characterised by the altitude and angle of inclination. The orbital inclination and altitude limit the maximum degree of latitude that a constellation can reach. As such, LEO **shells with an inclination of less than 70 degrees can no longer offer real global coverage.**
- The size of a communication satellite's field of view (FOV), which indicates the area on the Earth's surface that the satellite can cover from its orbit, is crucial for its operation. Like a beam of light, the satellite bundles the emitted radio signal into a 'satellite beam', which is shaped according to the radiation pattern of its antenna.
- The area where the beam intersects with the Earth's surface is referred to as the beam footprint,

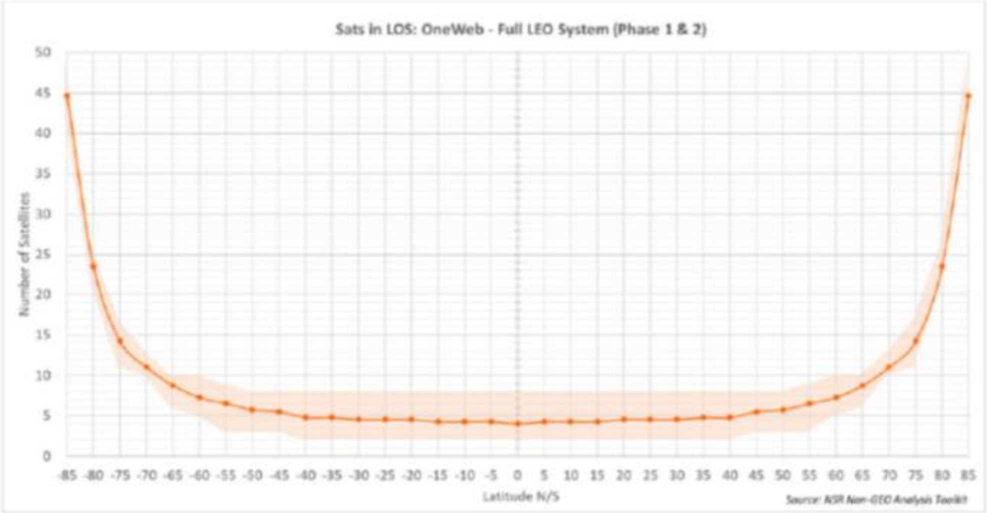


Shell	SpaceX Starlink – 53° incl. 550 km alt
Satellite overpass time	4.1 min
Orbit type & inclination	Inclined, 53°
Max. latitude reached	61° N/S
Number of orbital planes	72
Satellites per plane	22
Total satellites per shell	1584

StarLink (red) and OneWeb (black, elliptical) Beam Pattern & LOS satellites







New constellations main characteristics

	Orbit Inclination	Orbit Altitude (Km)	Satellites per shell	Total
O3B mPower	0° 90°	8062 8052	10 24	34
Telesat LEO	98.98° 50.88°	1015 1325	78 220	298
Telesat VLEO	37.4° 99.5°	1284 1000	45 72	117
Kuiper	33° 42° 51.9°	590 610 630	784 1296 1156	3236
Starlink LEO	53° 53.8° 74° 81° 70°	550 1110 1130 1275 1325	1584 1600 400 375 450	4409
Starlink VLEO	53° 48° 42°	345,6 340,8 335,9	2550 2450 2500	7500
OneWeb	87.9° 87.9°	1207 1207	660 1320	1980

SATCOM Bearer solutions

- Major available alternatives
  - **HTS GEO Ka-band** SatCom Service designed for broadband communication on the move on a global scale.
  - **LEO Ku/Ka-band** SatCom Service designed for broadband communication on the move on a global scale.
  - **GEO Ka-band** SatCom Service designed for broadband communication on the move on a regional scale
  - **GEO / LEO L-band** SatCom Service designed for narrow-band communication on the move on a global scale.

		Operational			Under development		
Frequency band		L	Ku	Ka	L	Ku	Ka
Orbit type	GEO	Inmarsat 4 (BGAN) Thuraya	Various (e.g. TPZ Global Platform)	Kasat Konnect Inmarsat 5 (GX)	Inmarsat 6		Konnect VHTS Inmarsat 6 Viasat 3
	MEO			O3B			O3B mPower
	LEO	Iridium Next Globalstar 2nd g.				Oneweb Starlink	Telesat Starlink

Available satellite solutions

	Thuraya	Iridium Next	Globalstar 2nd gen	Inmarsat 4 (BGAN)	Inmarsat 5 (GX)	Inmarsat 6	O3B	O3B mPower	Oneweb	Konnect	Konnect VHTS	Kuiper	Starlink	Telesat	Kasat	Viasat 3
Orbit type	GEO	LEO	LEO	GEO	GEO	GEO	MEO	MEO	LEO	GEO	GEO	LEO	LEO	LEO	GEO	GEO
Satellite number	1	66	24	3	4	2	20	11	1980	1	1	3236	11909 (+30000)	415	1	1
Orbit inclination (deg)	0	Near Polar	52	0	0	0	0	0 and 90	87.9	0	0	32 to 51.9	42 to 81	37.4 to 99.5	0	0
Orbit altitude (Km)	35786	780	1400	35786	35786	35786	8062	8052	1207	35786	35786	590 to 630	335.9 to 1325	1000 to 1284	35786	35786
Coverage type	Regional (Europe/Middle East)	Global	Global (70°N-70°S)	Global	Global	Global	Global (45°N-45°S)	Global (50°N-50°S)	Global	Regional (Europe)	Regional (Europe)	Global (55°N-55°S)	Global	Global	Regional (Europe)	Regional (Europe)
Frequency band	L	L	L, S	L	Ka	L, Ka	Ka	Ka	Ku	Ka	Ka	Ka	Ku/Ka	Ka	Ka	Ka
Service type	Narrow Band	Narrow Band	Narrow Band	Narrow Band	Broad Band	Narrow / Broad Band	Broad Band	Broad Band	Broad Band	Broad Band	Broad Band	Broad Band	Broad Band	Broad Band	Broad Band	Broad Band
Current deployment status	In operation	In operation	In operation	In operation	In operation	F1 launched dec.2021	In operation	Under developm.	400 satellites launched (20%)	In operation	Under developm.	Under developm.	1900 satellites launched (16%)	Under developm.	In operation	Under developm.
Data throughput per satellite (Gbps)	-	-	-	-	-	-	8	200	8	75	500	10	10	50	90	500
User max data rate (Mbps)	0,444	8 (1.5 to mobile terminals)	0,256	0,8	50	50	2.1	50	50	75	Target: 200	Target: 400	Beta test: 40-93 Target: 300	40	40	100
Inter Satellite Link	N/A	Yes	No	No	No	No	No	TBV	No	N/A	N/A	TBV	Yes	Yes	N/A	N/A
Latency (Order of Magnitude, msec)	600	Target: 40	60	300	300	300	150	150	32 (Average)	300	300	20 (TBC)	Beta test: 31-88 Target: 20	Target: 30	300	300

Railway Requirements and satellite solutions compliance (1/2)

Parameter	Key Aspect
Link availability	Lower frequency bands (i.e. L, S C) offer more favourable conditions than higher frequency bands (i.e. Ku , Ka - band) where worse weather conditions have to be supported
Reliability	End-to-end QoS requirements of a communication call/session shall be guaranteed according to user‘s SLA. Backup and/or redundancy (i.e. duplication) for critical elements can be assumed in most of the cases in order to reach MTBF and MTTR figures. This can be more easily supported in GEO environments
Error Ratio	Ad hoc mechanisms are nowadays provided in commercial communication standards (e.g. DVBS2/X/RCS2, etc.) to guarantee a high level of service continuity
Transfer delay	SATCOM transmission delay can be similar to the one provided by terrestrial systems only using non-GEO orbits (i.e. LEO or MEO). GEO satellites transmission delay could be accepted or not according to specific applications requirement
Delay jitter	IP level mechanisms are able to compensate the delay time variations between packets. Closed network solutions (i.e. Iridium, Inmarsat), which offer voice services with Circuit Switched, are not providing relevant differences in the quality of the voice services
Network registration delay	It depends on the network synchronization mechanism implemented by each specific solution. Systems requiring localization information are not meeting the requirements since cold acquisition time for GNSS systems are long
Call establ. delay	Closed network systems, which are using Circuit Switched for providing voice calls, are non-compliant

Railway Requirements and satellite solutions compliance (2/2)

Parameter	Key Aspect
Capacity	Higher frequency bands (e.g. X, Ku and Ka) can provide more capacity than lower frequency bands (e.g. L, S, C) where spectrum resources are much more limited
Bandwidth	Systems operating at low frequency bands (narrowband) are able to provide capacity to ETCS data and voice services, whilst SATCOM systems operating at high frequency bands (mainly Ku and Ka) can also provide broadband services, such as internet for passengers
Coverage	Most of the available systems are providing worldwide coverage
Mobility	Majority of the satelite solutions are going to meet this requirement; however, some of them shall implement additional mechanisms (e.g. Doppler compensation mechanism) to enlarge the range of supported errors required at highest speeds, up to 350 Km/h). Commercial standards like DVB-RCS include specific annexes for mobile environments, referred as DVB-RCS+M
Scalability	Solutions operating at higher frequency bands are going to provide more scalability than the ones operating at lower bands where the spectrum resources are more limited
Types of Terminals	Restrictive type of terminal in terms of size, weight and power (SWaP) , onboard terminals are more complex and expensive, since directional and steerable antennas shall be used
Security	Commercial SATCOM solutions generally do not provide mechanisms to prevent intentional attacks and/or to counteract intentional RF interferences (i.e. jammings) at bearer level. However, some solutions (e.g. Inmarsat BGAN) provide authentication and encryption at L2

Telespazio: preparing the future

Today

- **One Web** for services distribution and teleport services
- Distributor and teleport services of **Eutelsat Ka-Sat** HTS services
- Distributor and teleport services of **Inmarsat GX** HTS services and **BGAN**
- Distributor and teleport services of future **Konnect** Ka-Band VHTS
- Distributor of **Iridium** and Iridium Certus services
- Provider of **Galileo Operations** and Distribution services

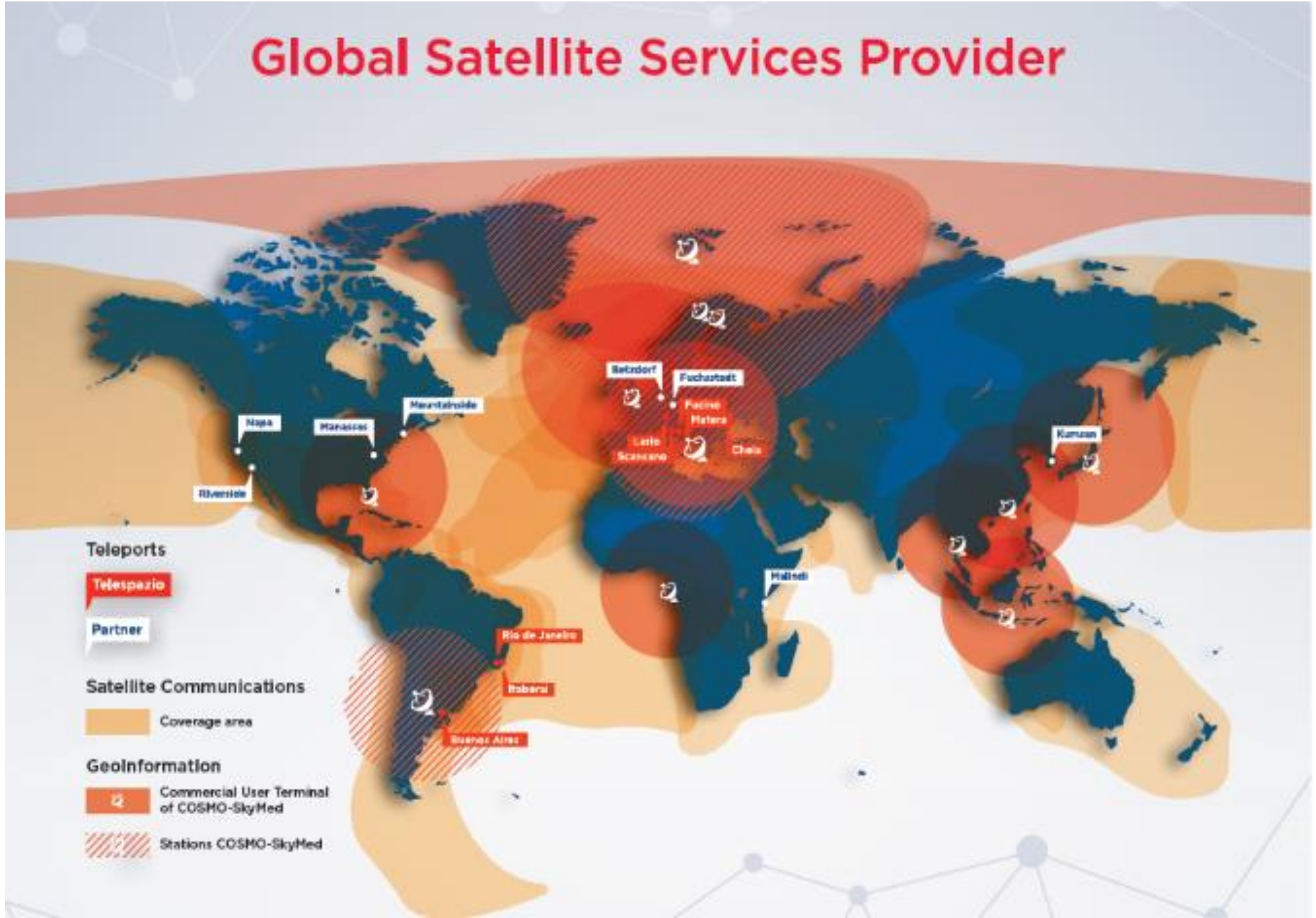
Tomorrow (in progress)

- Distribution services of **Telesat LEO** and teleport services
- SES for distribution of **O3B m-Power** services
- Intelsat for distribution of the **Epic** services

One Web cluster installation at Telespazio Scanzano teleport (Sicily)

Teleport services for INMARSAT at Telespazio Fucino Space Center

Telespazio: From Regional to Global



Global coverage for mobility, LEOP services, Mil & Gov, etc.

→

Telespazio Global Ground Network: support new constellations and services through a "Ground as a Service" approach

Telespazio as a partner to build the future together

- Active monitoring of deployed assets for global proactive maintenance and failure prevention support
- Enhanced Narrowband and Broadband Mobility connectivity solutions
- Enhanced, secure, resilient, low latency, low cost connectivity solutions for transport critical applications
- Monitoring of transport critical infrastructures
- Fiber-like connectivity for transport business application virtually anywhere

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FOR YOUR ATTENTION

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