Evolution of Wireless: From Villa Mondragone to LEO Satellites and Beyond

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Villa Mondragone: Historial Site of the European Physical Society
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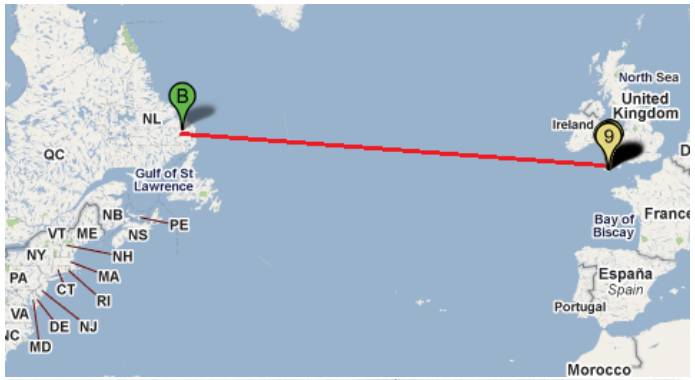
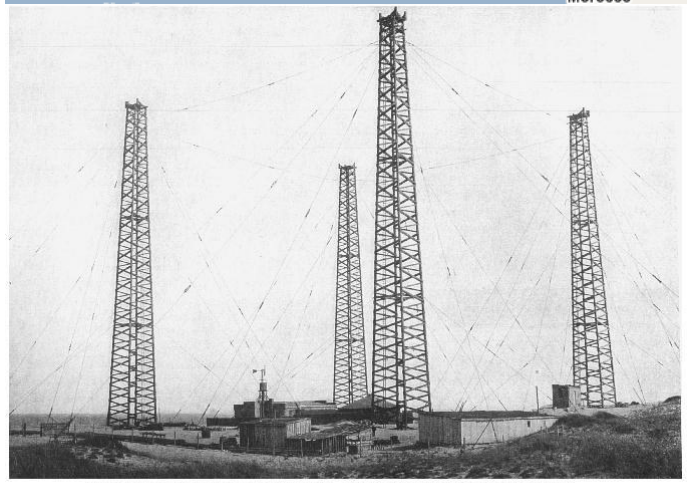
Enabling Global Connectivity…and beyond

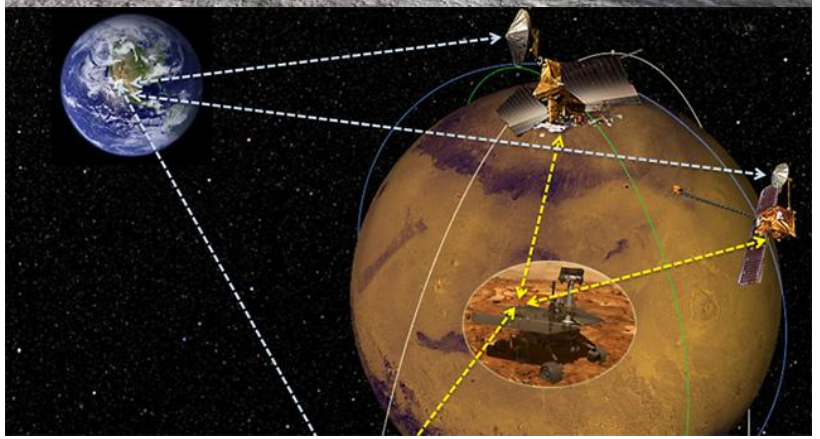




THE WIRELESS TELEGRAPH STATION AT SOUTH WELLFLEET, MASSACHUSETTS
Showing the simplicity of the apparatus

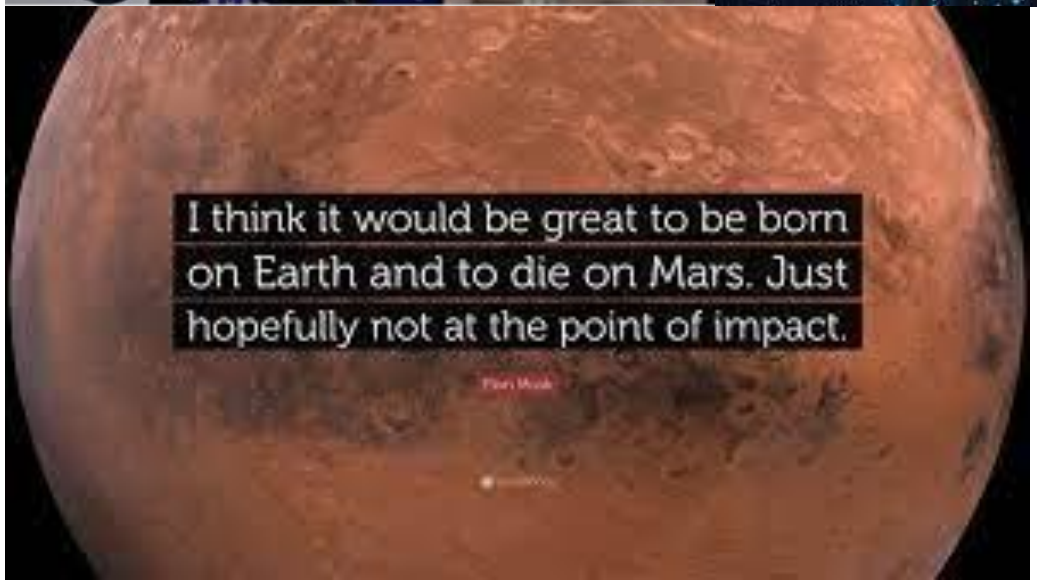
Connecting two continents

Connecting Anyone Anywhere on Earth

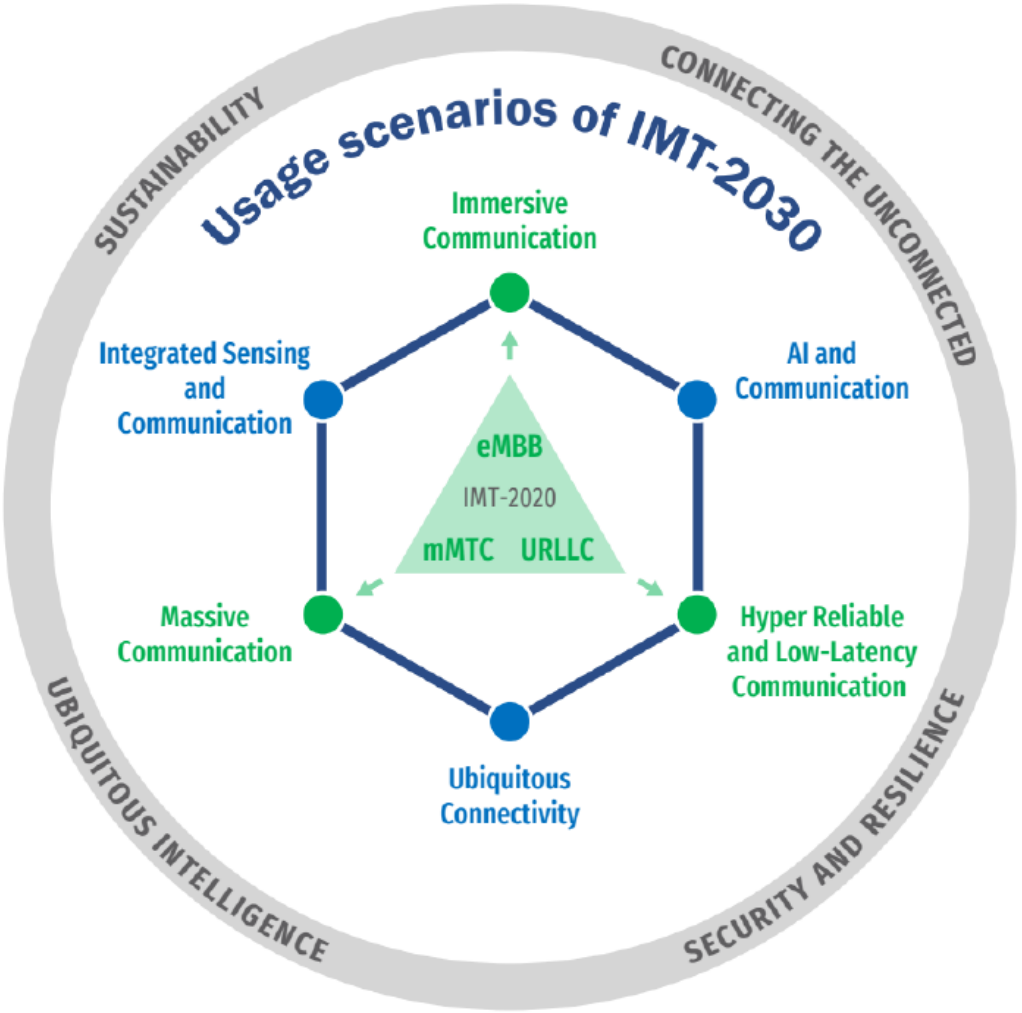


Connecting Anyone/Anything in the «Universe»

Not only Signals but also Visions

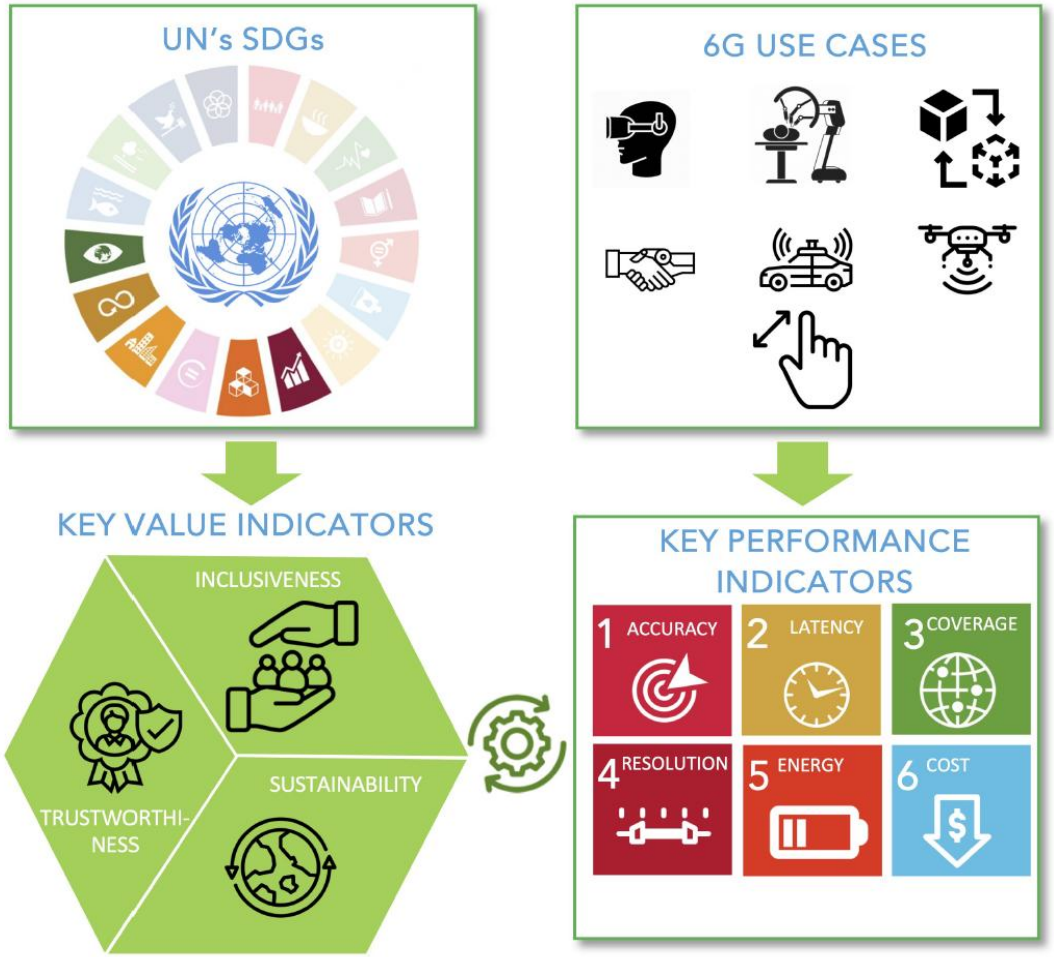


6G – The next generation of mobile network



6G – From KPI to Key Value Indicators (KVI)

Subset of the UN's SDGs
#8 - Sustainable development
#9 - Industry, innovation, and infrastructure
#11 - Sustainable cities and communities
#12 - Sustainable consumption and production
#13 (Climate action))



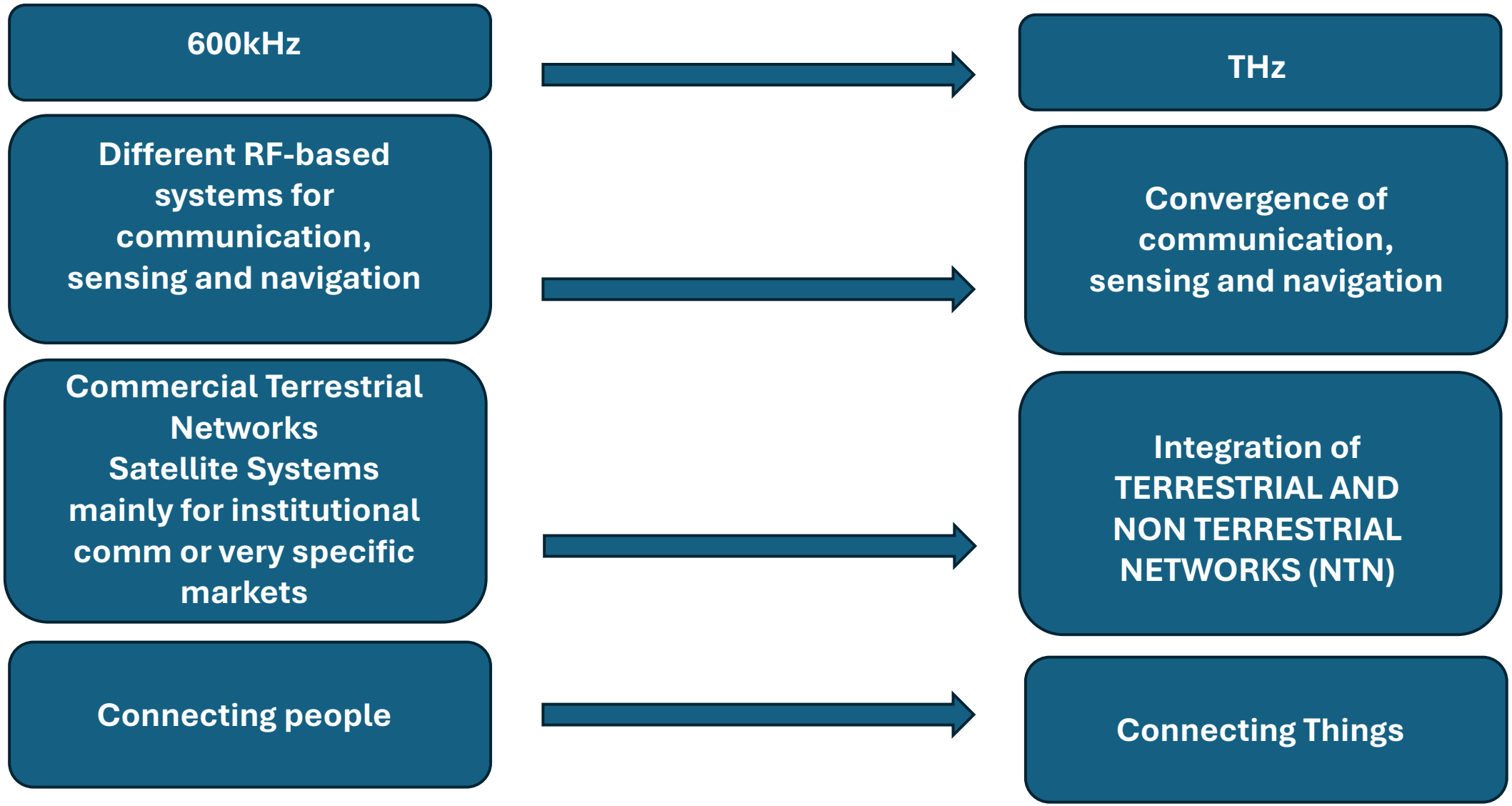
Hexa-X project Deliverable D1.2, 2021. [Online]. Available: https://hexa-x.eu/deliverables/

Sustainability: environmental and economic domains (support to long-term economic growth)

Inclusiveness: it aims to foster increased participation and mitigate digital divides, promoting an equitable technological landscape.

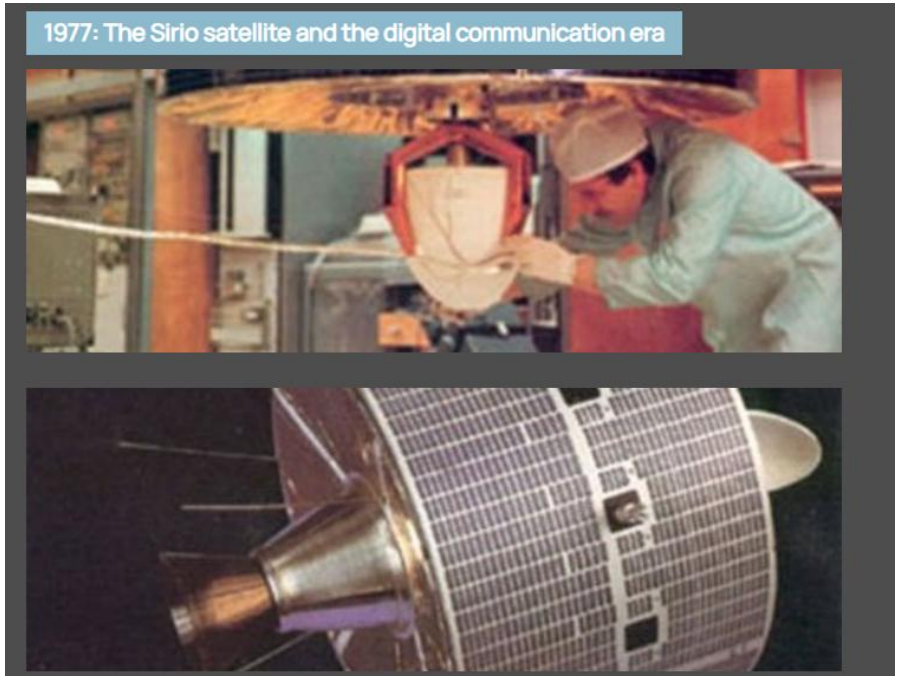
Trustworthiness: it encompasses security, robustness.and privacy

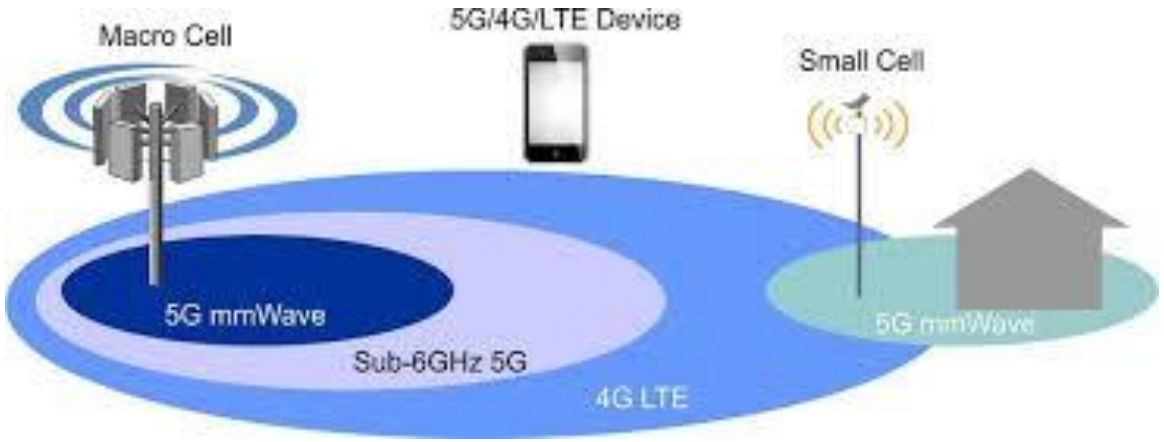
From the beginning of RF wireless comm to 6G



RF Spectrum –Higher frequencies?

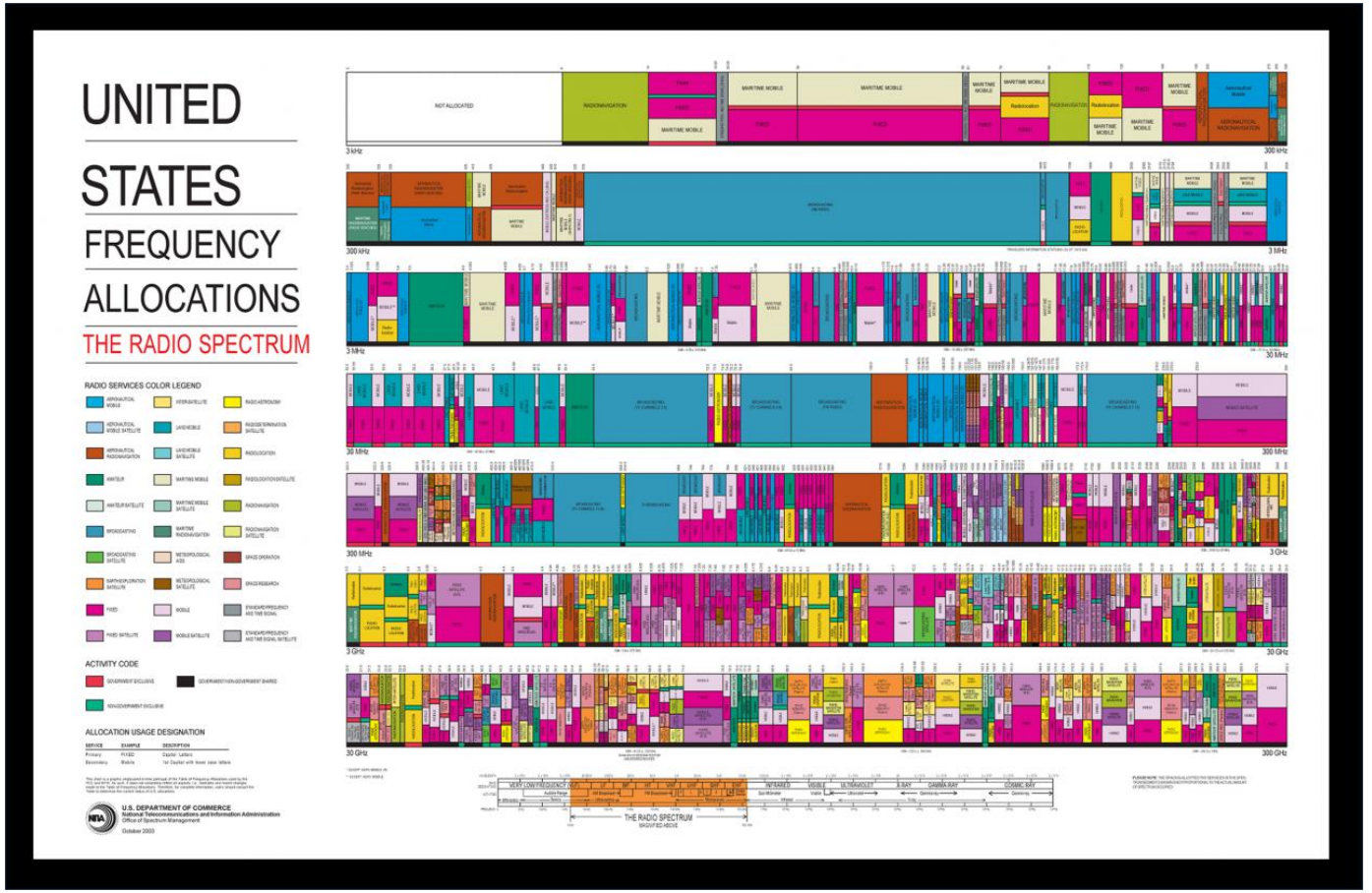
The use of higher frequencies has been pioneered by satellite communication systems (SIRIO in 1977 for 18GHz)





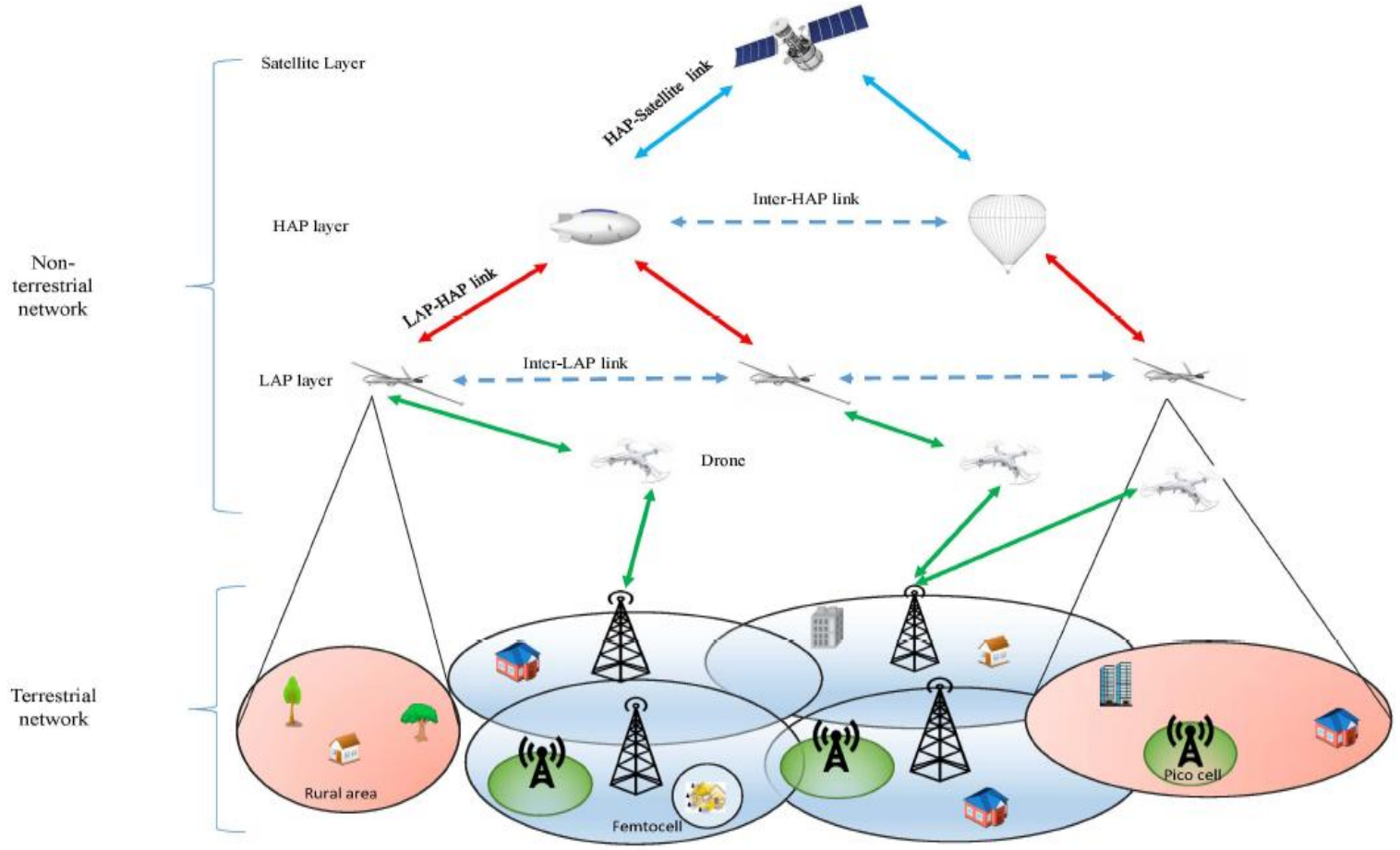
5G will use millimeter waves frequencies (around 28GHz) with smaller cells

RF Spectrum – Congested (or polluted)?



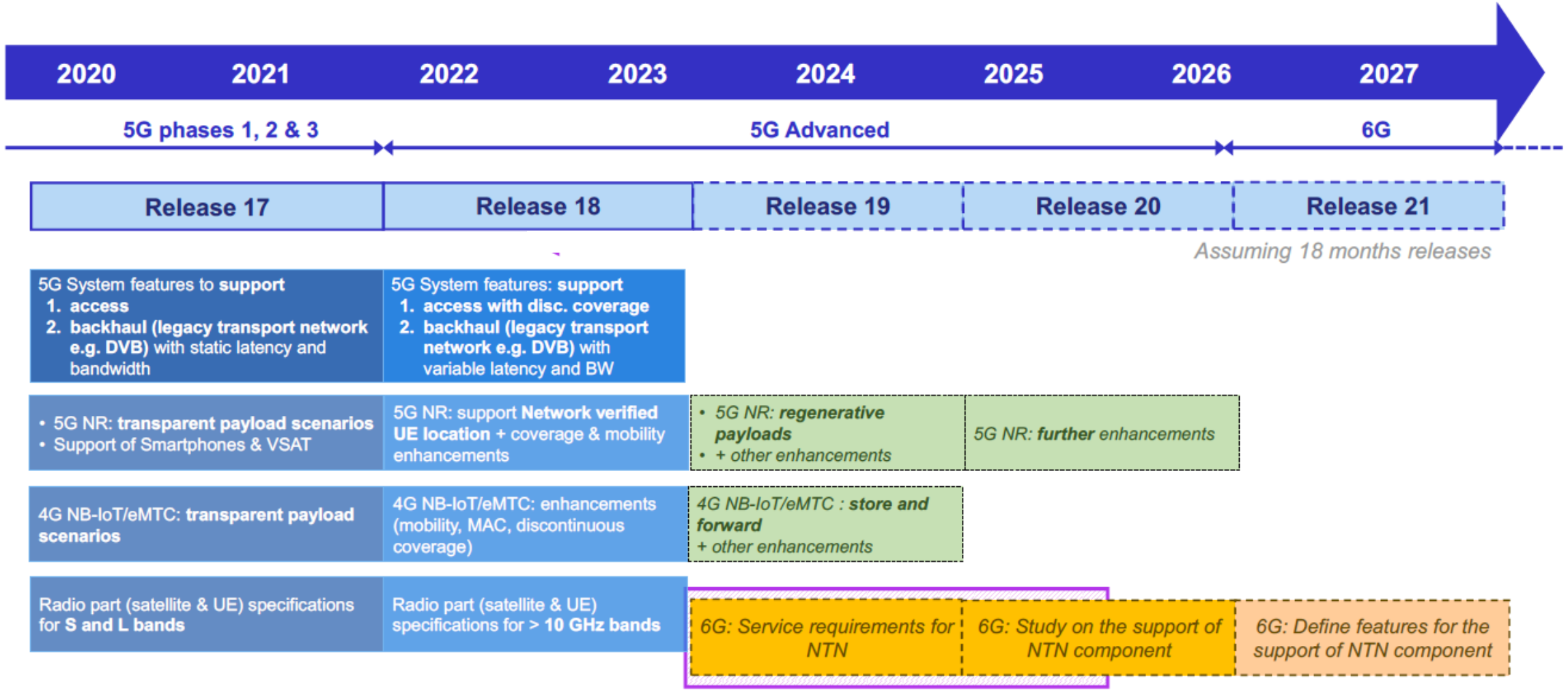
One key issue: SMARTER use of the RF Spectrum

Integration of Terrestrial and NTN



Effort in 3GPP to integrate Non Terrestrial Networks (NTNs) started in 2018

3GPP Standardization path toward the integration



Beyond 5G aims to TN optimization, Minimum impact to support NTN

6G aims to the joint TN-NTN optimization

(6G-NTN project, www.6g-ntn.eu)

Disruptive (uncontrolled) Space Systems Evolution

- 2023 is the year more satellites than ever have been launched: around 2900 satellites (2000 the ones of the Starlink constellation)
- 96% of them are *small satellites* with a mass between few kg to 600 kg.
- Between 2013 and 2021 the overall *throughput* per kilo of communication satellite weight has increased of 6 times
- The production cost per Gbps of capacity has decreased of 90%.
- The satellite service cost is 1/10 of the cost in 2013 and the number of broadband customers has increased on 50%
- The cost of launches in LEO orbit has decreased of 95% in the last 10 years.

Disruptive (uncontrolled) Space Systems Evolution

- «Space» has become a real opportunity for business (the New Space Economy)
- Along with the tradition space-industry actors, an increasing number of **non-space companies** are developing new products and solutions for space applications
- Customers are **not only institutional customers** but also private ones and belonging to different sectors (assurance, energy, transportation, agriculture)

Mega-costellations in LEO Orbit

STARLINK (SpaceX)

- Broadband services (in principle, 500Mbps, experimented 170Mbps and depending from the actual number of users)
- More than 7000 active satellites
- More than 20000 planned satellites
- In different orbits between 300-550km
- More than 100 launches per year

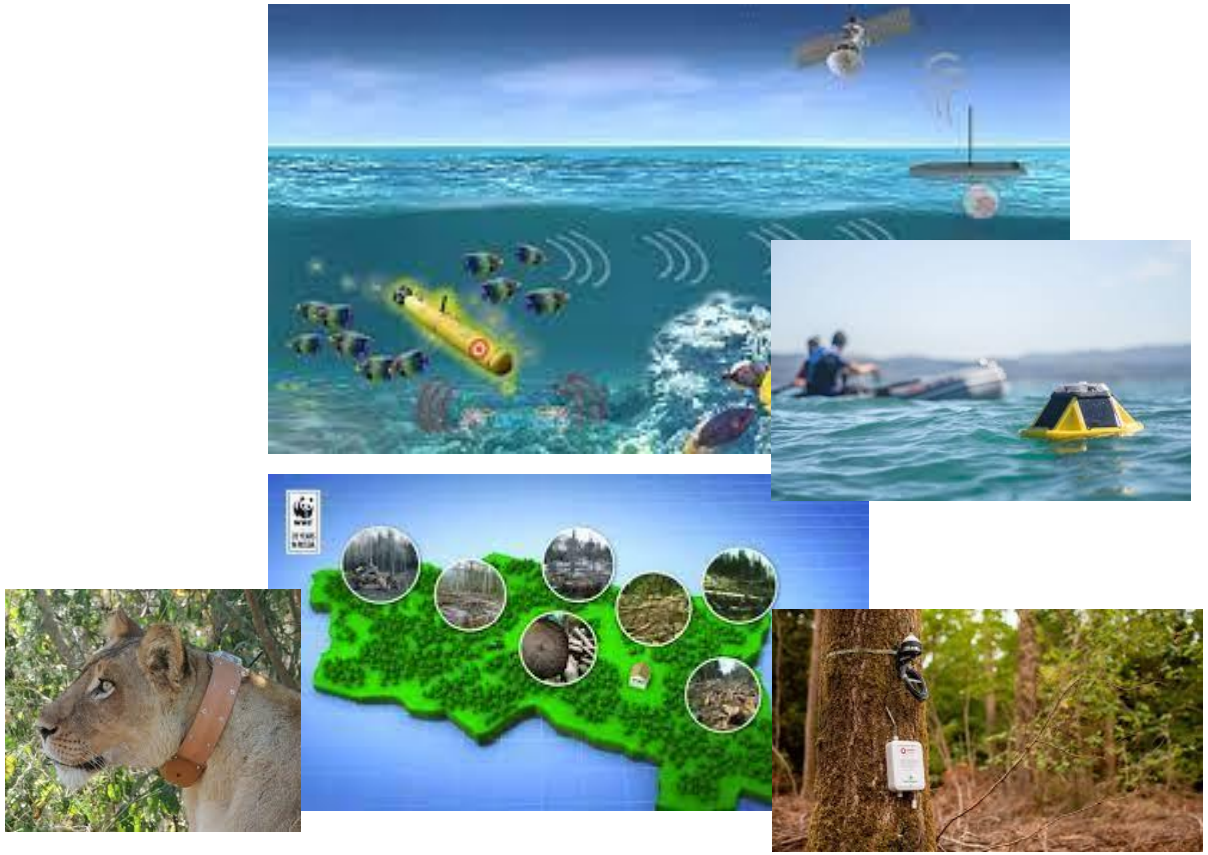
OneWeb (fusion with Eutelsat in 2023)

- Broadband Services
- 600 satellites
- 1200km of altitude

- **Vertical Model -** complete control on the production, launch and service
- **A «disposal» approach for satellites development**

Not only Broadband - Internet-of-Remote-Things (IoRT)

Environmental monitoring/disaster management



Critical infrastructure monitoring/smart grid applications

Standalone Constellations for IoRT

The recent and growing interest in DtS IoRT services is pushing to the development of **new satellite constellations** specialized for this type of service

Kepler - 19 cubesats in orbit at 575km of altitude

Astrocast – 18 nanosatellites in orbit, 100 nanosatellite planned, will be complete by 2024

Lacuna – launched 6, planned 240 satellites at about 500km altitude, it implements a LoRa demonstrator

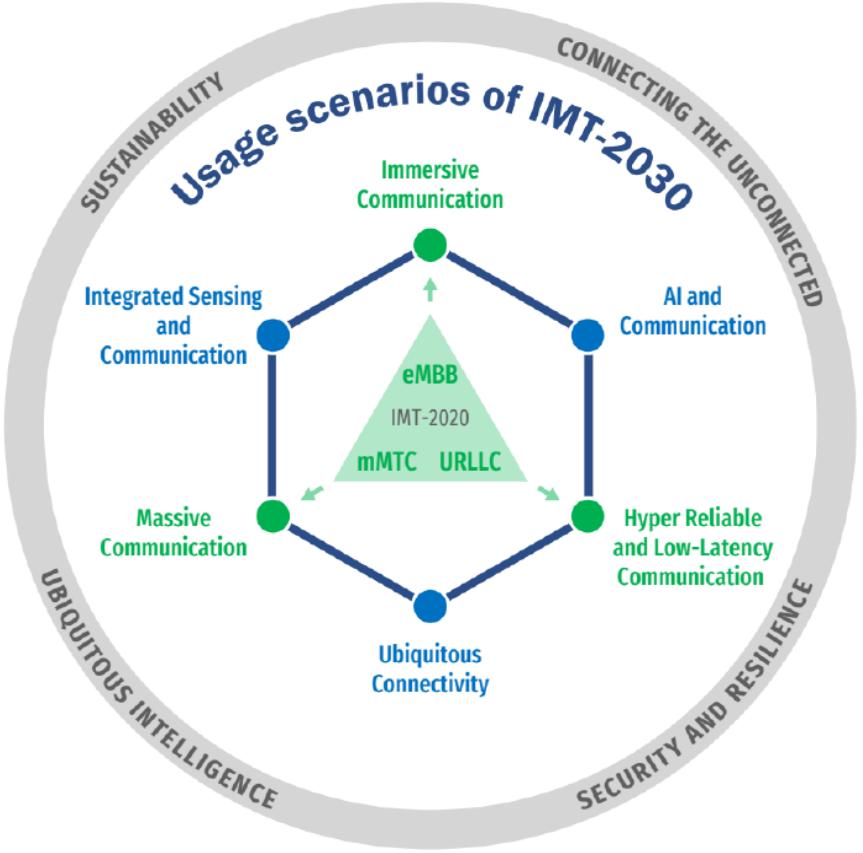
Sateliot – planned 100 cubesats (1 launched) it implements a NB-IoT demonstrator

Space Systems in 6G

HOW SPACE-BASE CONNECTIVITY EMPOWER PEOPLE AND COMMUNITIES

Among the 6G usage scenarios Space Systems are expected to contribute to:

- **connecting the unconnected**
- **security and resilience**
- **sustainability**



Space Systems in 6G

HOW SPACE-BASE CONNECTIVITY EMPOWER PEOPLE AND COMMUNITIES

Connecting the unconnected

- In development countries (where still millions lack internet access or real-time communication tools) - Education and telehealth services but also to increase job opportunities
- In disaster zones (Earthquake….War)

New Business Opportunities and Research and Innovation Development

- Universities, Start-ups and even developing countries are able to launch missions

Space Systems in 6G

HOW SPACE-BASE CONNECTIVITY EMPOWER PEOPLE AND COMMUNITIES (NOT JUST CORPORATIONS OR NATIONS)

Collecting data from wide/remote areas

- Developing new type of business using these data
  - Agricultural data for farmers

- **Protecting the Earth and the Life on the Earth**
  - Climate monitoring and early warning systems
  - Deforestation tracking
  - Ocean health and pollution detection

Urgent Challenges: Space Sustainability

Extremely Crowded Environment

- **7.500** active satellites
- Generation 1 of SpaceX Starlink will by itself consist of **11,926**satellites and generation 2, **30,000** more.
- OneWeb, Amazon Kuiper and China SatNet all together will deploy over **20,000** satellites
- **330 million** pieces of space debris
- Including **36,500** objects bigger than 10cm (old satellites, spent rocket bodies, tools dropped by astronauts orbiting Earth)

Urgent Challenges: Space Sustainability

Interference to astronomical observations

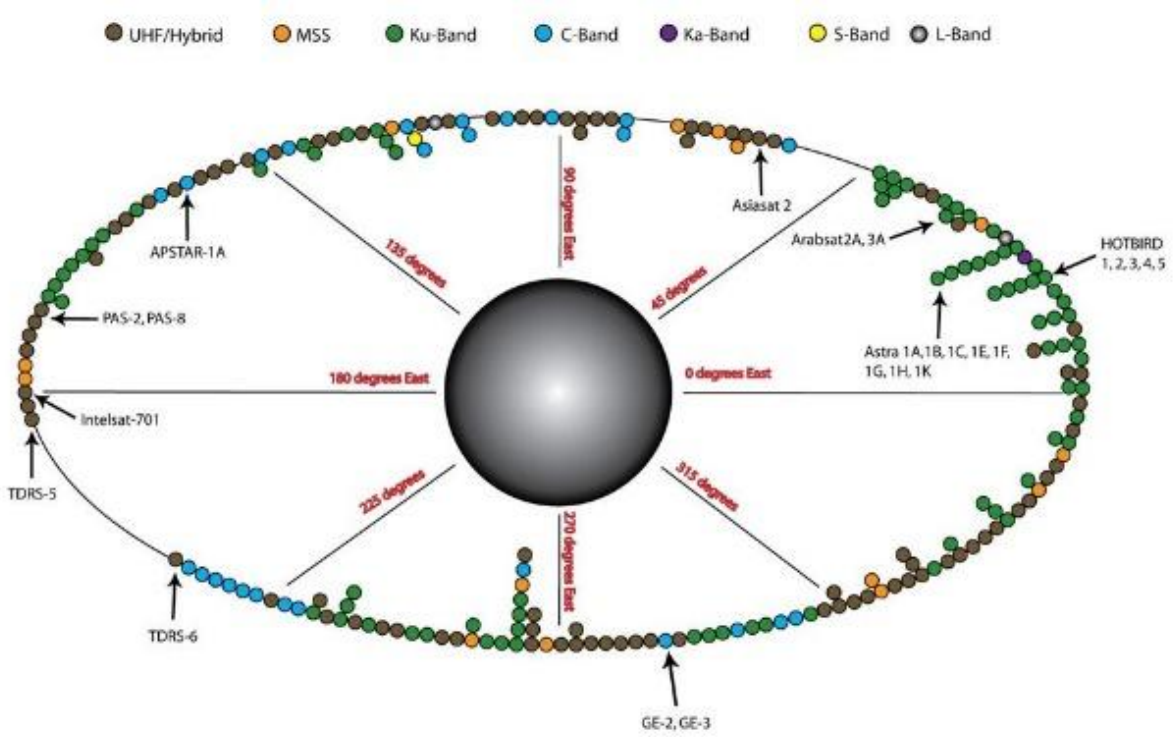
Long exposure star trail image taken at Hehuan Mountain, Taiwan

Urgent Challenges: Space Sustainability

The Space is NOT SAFE

'Increased' **intentional threats** but also **unintentional threats** such as:

- ❑ RF interference and need of a complex spectrum management
- ❑ High probability of collisions, further increasing the debris



Urgent Challenges: Space Sustainability

The Space is NOT SAFE

Reducing the impact of already produced debris/pollution

a) Collision avoidance is one of the main approach

- most of the risk comes from very small and not trackable “pieces” and there the only option is to AVOID the generation of debris

b) Removal is another key approach

- it is expensive and technically daunting

c) Operators MUST adopt a responsible design and operational practices

A solid regulatory framework is needed to support a responsible growth of the Space industry and such a framework is MISSING!

Urgent Challenges: Space Sustainability

Sustainability-by-Design Approach

Is it possible to design satellite systems whose missions can be changed in the future?

Satellite systems whose resources can be reused for providing novel services instead of launching novel infrastructure elements?

Satellites that could be recycled after their mission has ended?

Urgent Challenges: Space Sustainability

Sustainability-by-Design Approach – 3 pillars

- Backward Compatibility – Providing new services “reusing” already deployed infrastructure (e.g., **use of signal of opportunity**)

- Forward Compatibility – new satellite systems/missions that are so “open” and flexible that can be adapted to provide different services in the future (e.g., **hosted payload, fused LEO, Federated Satellite Systems**)

- More efficient use of the **multi-layered NTN architecture**

Urgent Challenges: Risk of Monopoly

Urgent Challenges: Risk of Monopoly

DOMINANCE OF STARLINK → Vertical Model: complete control of production, launch and service
→ barrier to enter

INSTITUTIONAL WORRIES → OCSE and the Secure World Foundation reported the spectrum hoarding (rush to book frequencies/orbits without immediate use)

MARKET RISKS →
- Concentration of space resources in few «hands»
- Oligopolization of global satellite services
- Threat to digital sovereignty and technological autonomy

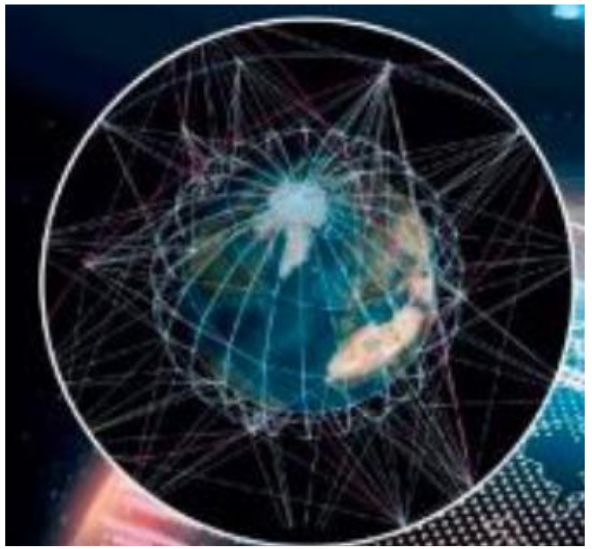
The European answer: $IRIS^2$

290 satellites (LEO + MEO)

- more sustainable

IRIS² aims to empower already existing infrastructure

Being interoperable with public and military terrestrial and not terrestrial network



Secure communications

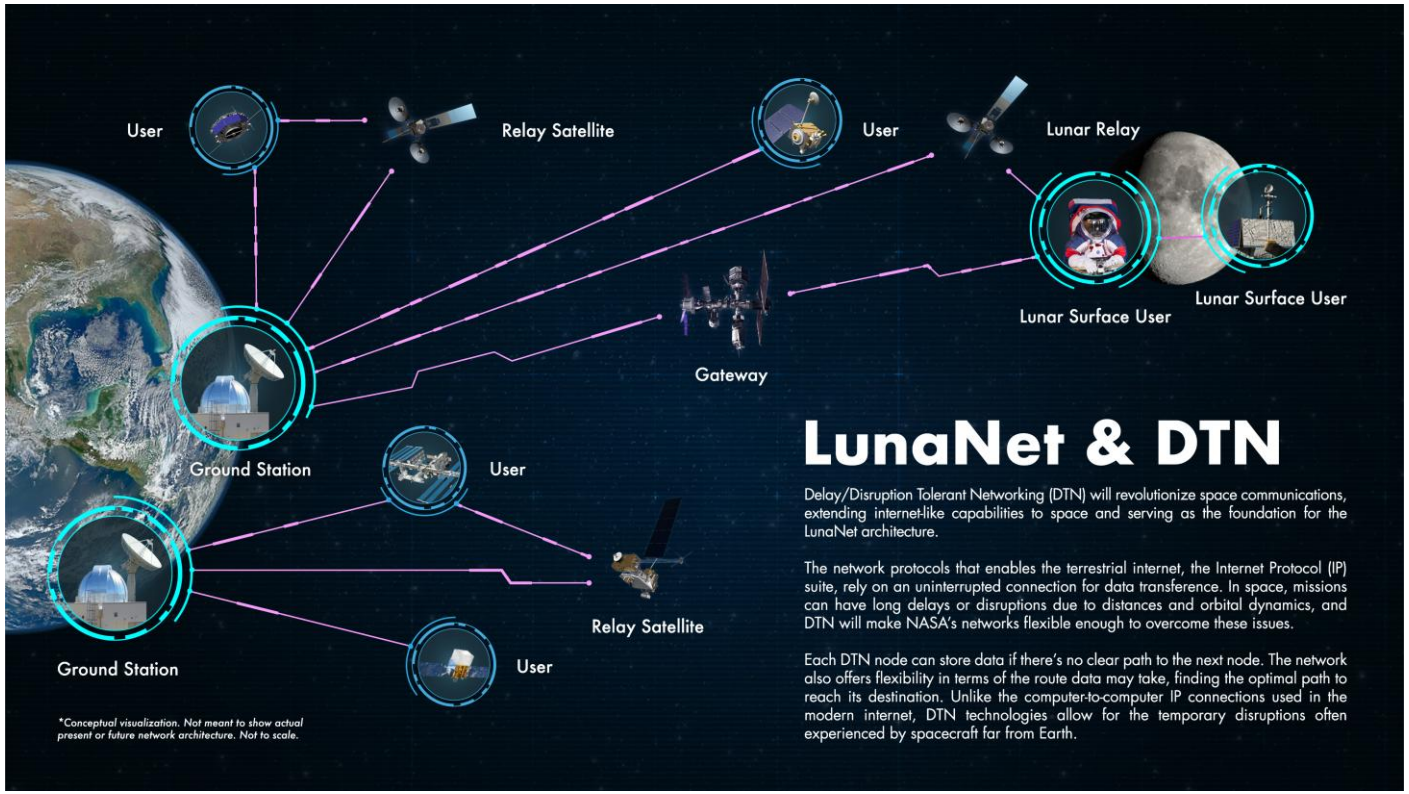
Reduction of the extra-EU operators dependence

Budget: 10,6 mld €, 61% public UE/ESA funds

Operative by 2030

Can the cooperative/integrated and more sustainable-by-design European approach be a winning alternative?

From Global Connectivity to Moon Connectivity



[Image: NASA/Reese Patillo]


The coming of the wireless era will make war impossible, because it will make war ridiculous.
— Guglielmo Marconi —
AZ QUOTES