



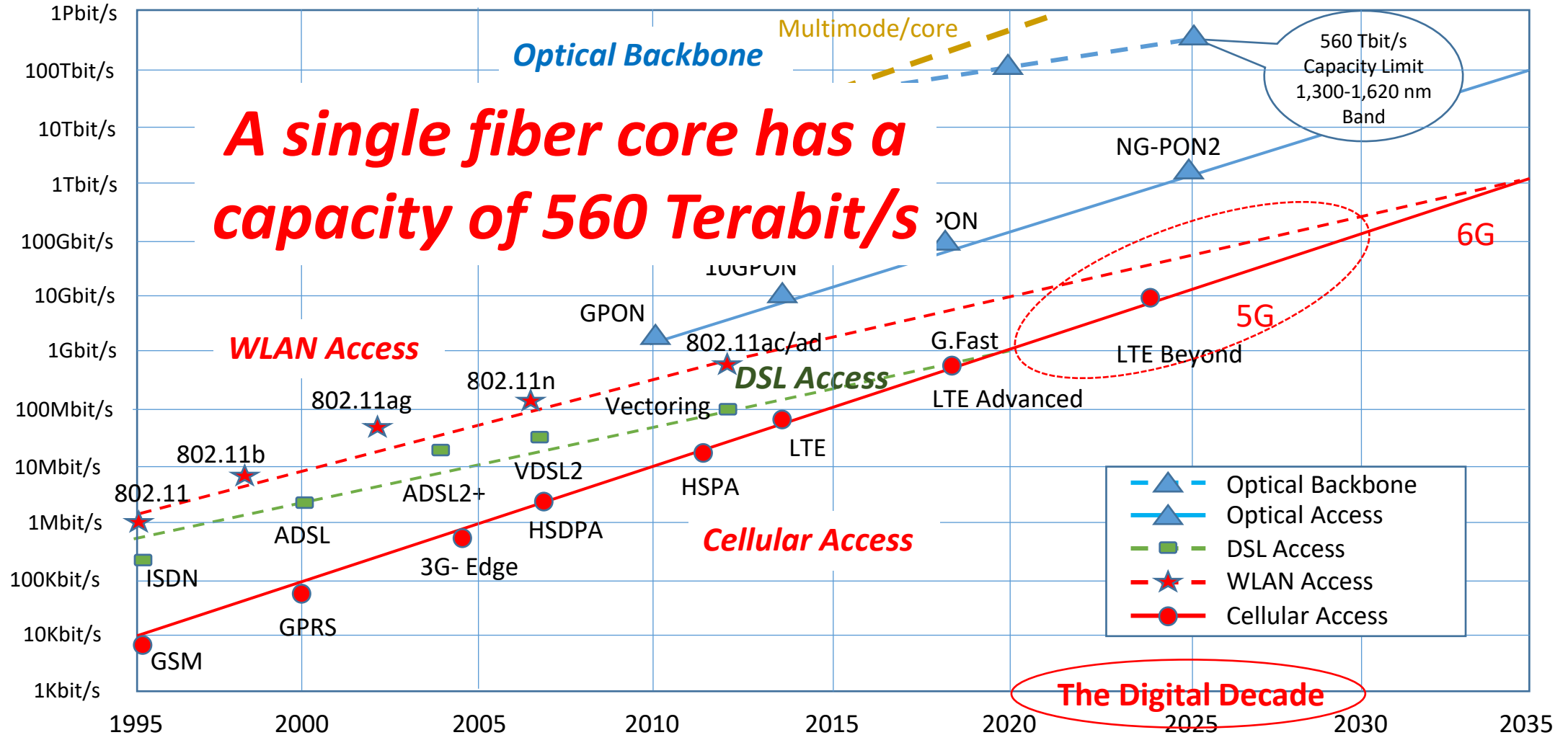
LEO Satellites vs. Terrestrial Networks

Maurizio Dècina
Politecnico di Milano

Seminario ASTRID, Roma, February 18th, 2025



Terrestrial Networking Technologies



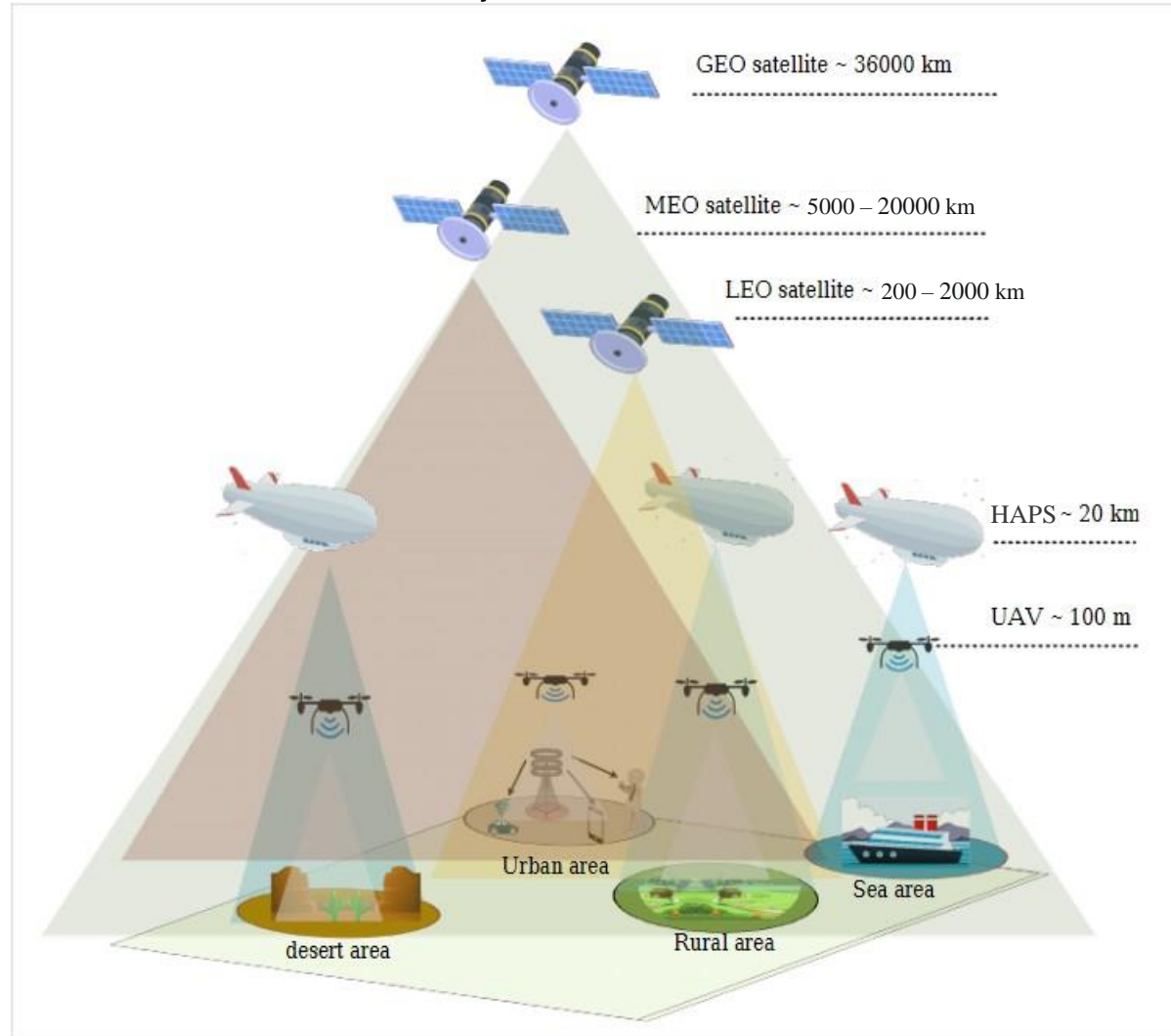
Source: M. Dècina, 2014, based on data by Bell Labs, G. Fettweis, and others

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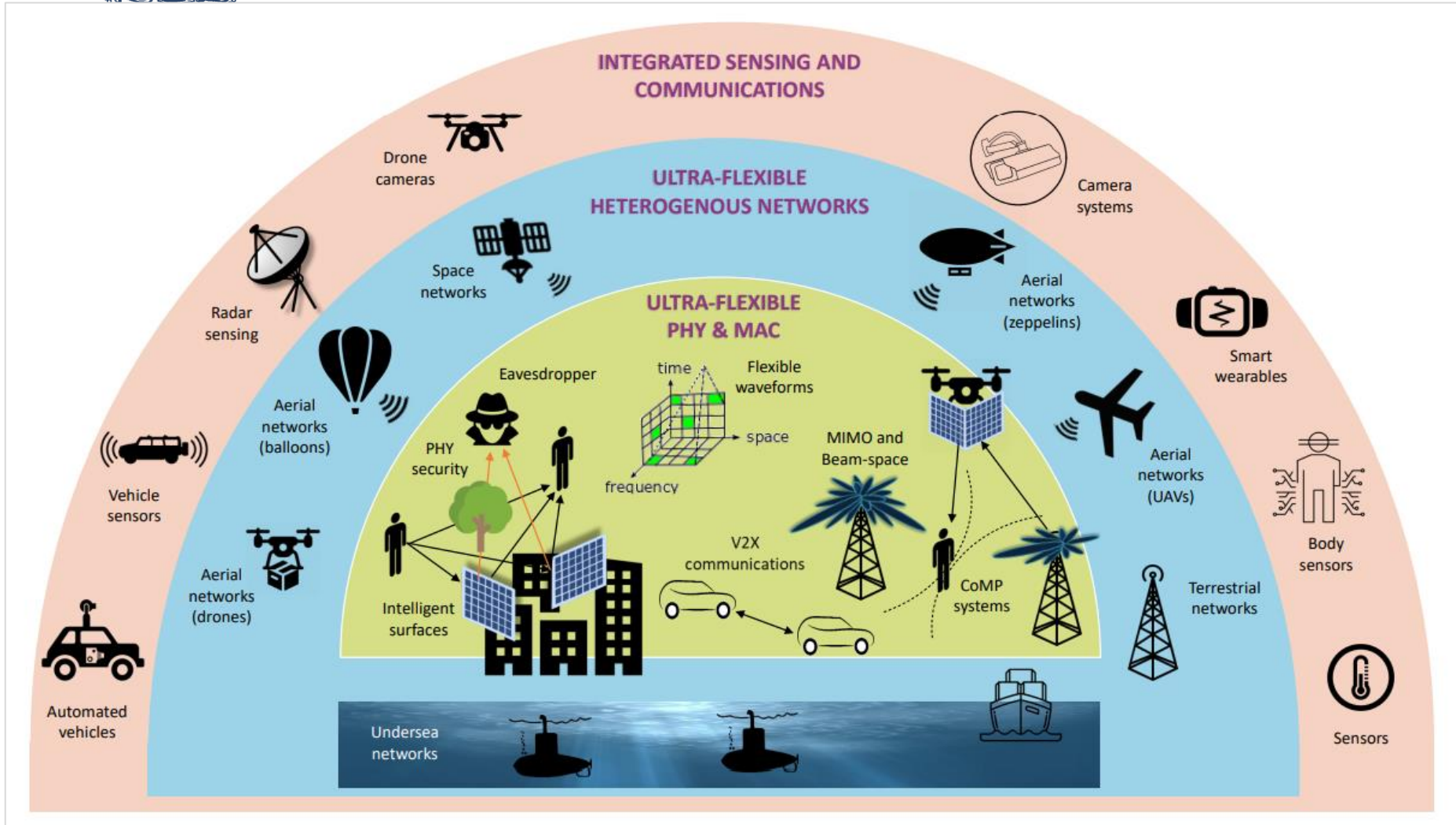


Space Networking Technologies Satellites, Drones & Platforms





6G Heterogenous Networking Objectives



- Heterogeneous networks are expected to play a significant role in 6G networks, **providing more potential for spatial spectrum reuse and higher quality of service** than homogeneous networks
- According to ISAC (**Integrated Sensing and Communications**) paradigm, that envisage the integration of sensing capabilities into future communication networks, **6G will play a significant role in creating intelligent and context-aware networks** that can adapt to various environmental conditions and user requirements

Source: ITU, "6G Vision", 2020

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Starlink Satellite System Features



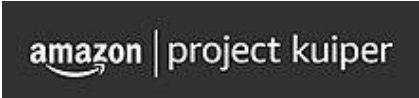
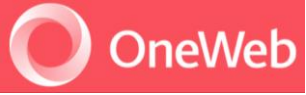



Starlink Constellation

- Space X - Starship
- Starlink: 5,000,000 mobile & fixed customers (residential, roaming, boats & business) world-wide, of which 50,000 in Italy
- Starshield: embedded facility to serve Administration, Defense and Emergency Services
- Around 7,000 satellites at 550 km, around 300 2G satellites are being launched, bigger and more suited to the “Direct To Cell” D2C service
- Constellation of 12,000 1G satellites and 30,000 2G = 42,000 satellites
- Space X & Telespazio (Leonardo & Thales) are partners



Some LEO Satellite Constellations

Satellite System	Country of Origin	Gateways/ Users Spectrum	Initial Total Throughput	Latency (ms)	Orbit (km)	Type of Service	Operational	Connectivity Coverage	Planned Constellations Size
 Amazon – Project Kuiper	USA	Ka band/ Ka band	n/a	40	590-630	Broadband service sold directly to consumers	n/a	n/a	3250
 OneWeb (Eutelsat Group)	UK/ France	Ka band/ Ku band	1,56 Tbps	50	1100- 1200	Backhaul/ Mobility	Q4-2023	Northern Latitudes, above 50	650
 Starlink (SpaceX)	USA	Ka band/ Ku band	23,7 Tbps	40	540-570	Broadband service sold directly to consumers	2020	N. America, N. Europe, Pacific	12000/ 30000

<https://digitalregulation.org/regulation-of-ngso-satellite-constellations/>

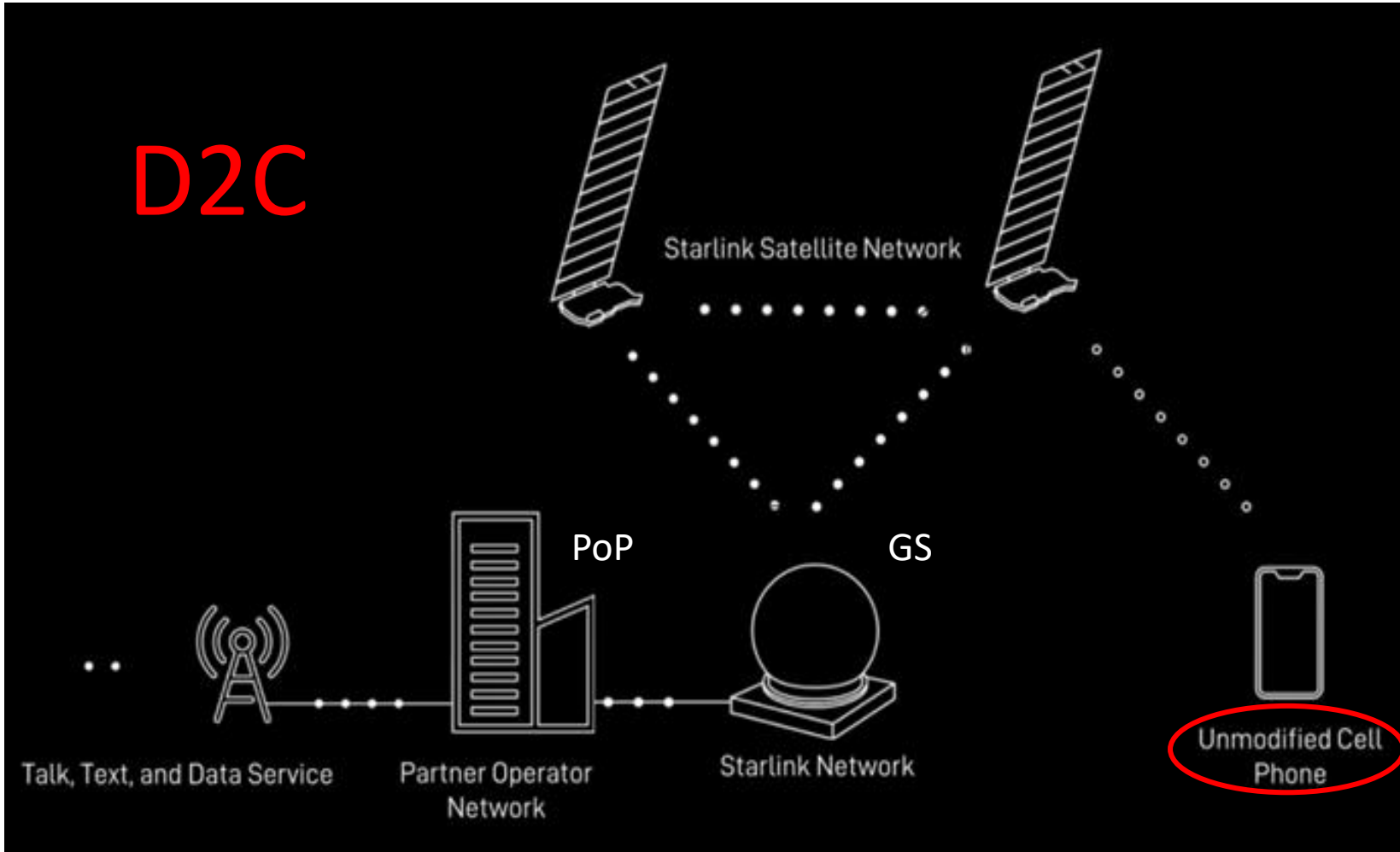


Some LEO Satellite Constellations

- EUTELSAT owns the OneWeb constellation of 648 Satellites at 1,200 km, plus the 80 of IRIDIUM at 800 km
- AMAZON with project KUIPER aiming at a Constellation of 3,250 Satellites at 650 km and just launched the first two (50% satellites by mid 2026). Aims at communication bandwidth greater than those of Starlink
- IRIS 2 is the EU project for a constellation of LEO/MEO/GEO Satellites for Administration, Emergency and Defense. 300 satellites, 10 b€ budget, system ready by the end of the decade: 2030
- QIANFAN & GUOWANG, two Chinese Companies aiming at LEO Constellations of 15,000 (54 launched) and 13,000 Satellites, respectively



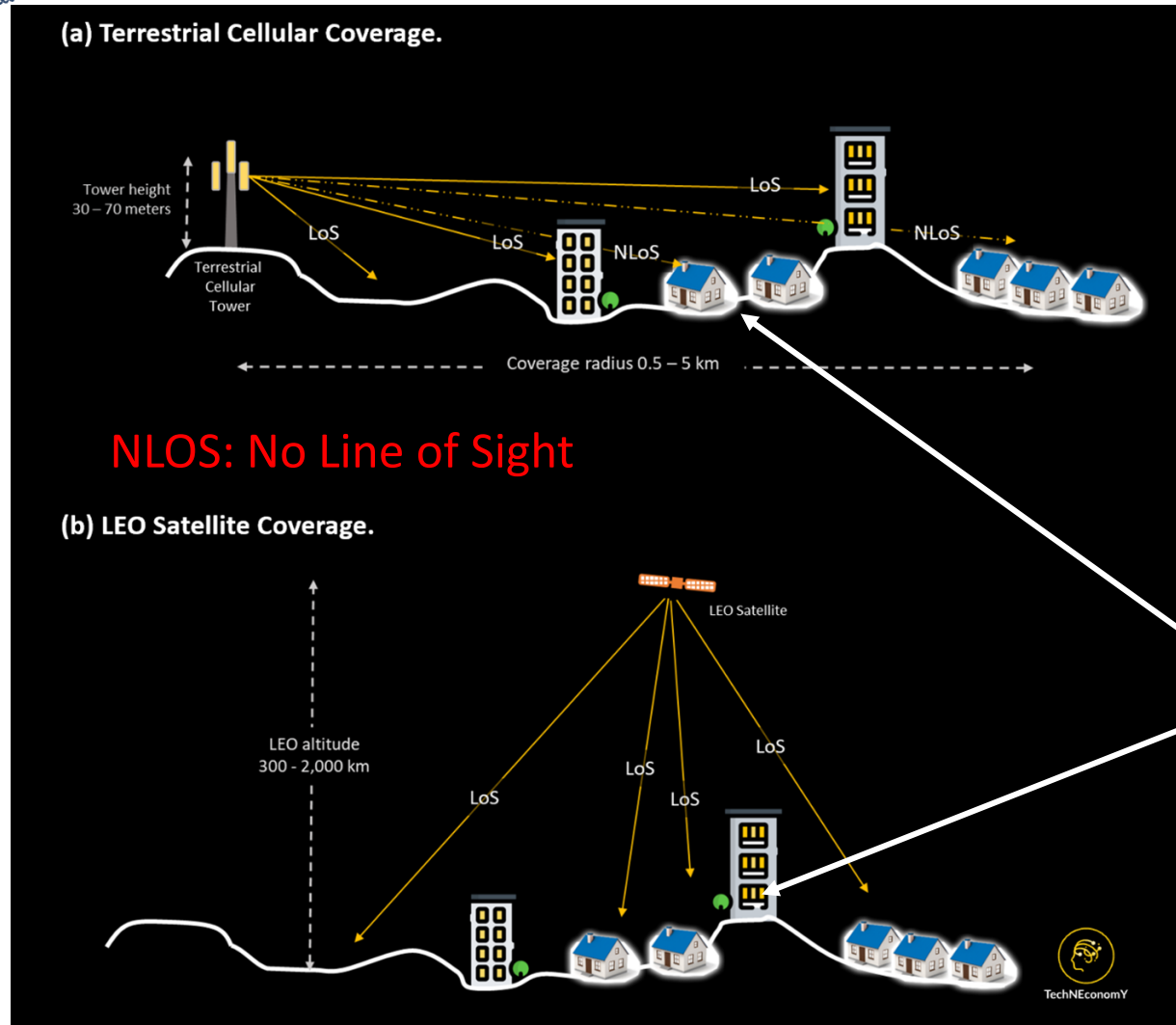
LEO Satellite Direct To Cell Coverage



- **T Mobile offer via Starlink**
(5G (Samsung & Apple phones))
- **Vodafone offer via Buebird**
(AST SpaceMobile: 5 over 248 satellites launched; 4G/5G phones)



Terrestrial Cellular vs. LEO Satellite Coverages



NLOS: No Line of Sight

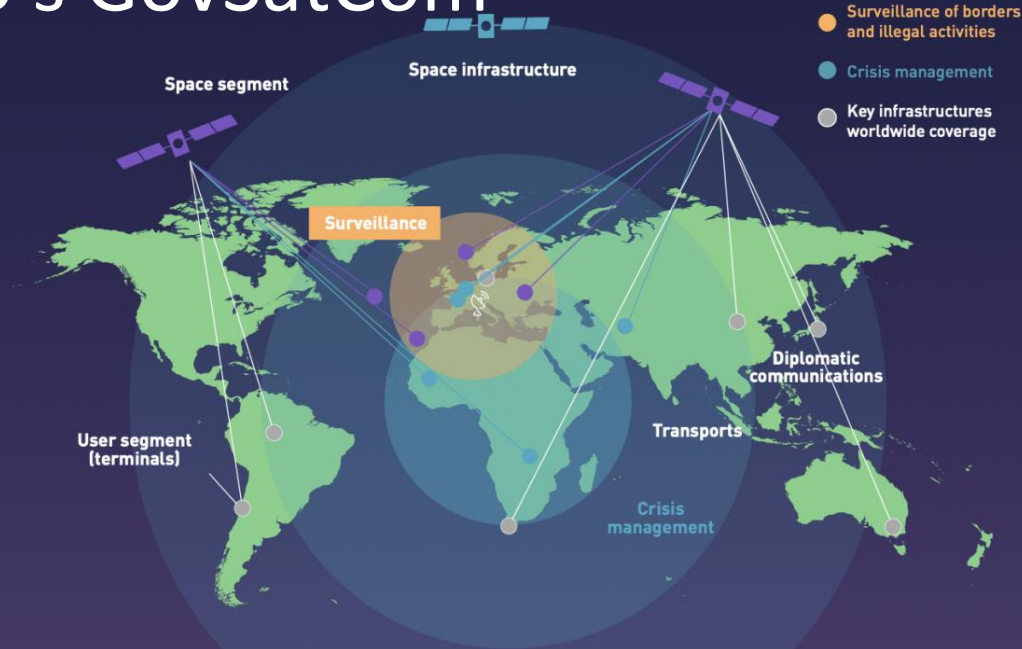
The idea of D2C-capable LEO satellite networks making terrestrial cellular networks obsolete is fraught with practical limitations. **LEOs struggle to match terrestrial networks' capacity, reliability, and low latency in urban and suburban environments**

- 80% cellular calls are indoor
- NLOS terrestrial coverage
- Poor satellite coverage of multi-floor buildings
- Critical current phones' uplink channel

Source: Strand Consult, 2025



EU's GovSatCom



GOVSATCOM FOR CRISIS MANAGEMENT

GOVSATCOM will provide both military and civilian responders with:

- Guaranteed communication services enabling audio/video communication.
- Data exchange between the teams in the field, with their rear bases and with their command & control centres.



GOVSATCOM FOR BORDER AND MARITIME SURVEILLANCE

GOVSATCOM will guarantee:

- Near real-time distribution of information from surveillance platforms and sensors to border and maritime surveillance agencies.
- Connectivity between EU authorities, national authorities and mobile patrols.

GOVSATCOM FOR KEY INFRASTRUCTURE MANAGEMENT

GOVSATCOM will support:

- EU and Member States' diplomatic networks with an access to reliable and secure satellite communications independent from the hosting state, anywhere in the world.
- Key infrastructure managers with appropriate communication services when these are critical to their activities.



Ital-GovSatCom



The Dark Side of LEO Mega Constellations

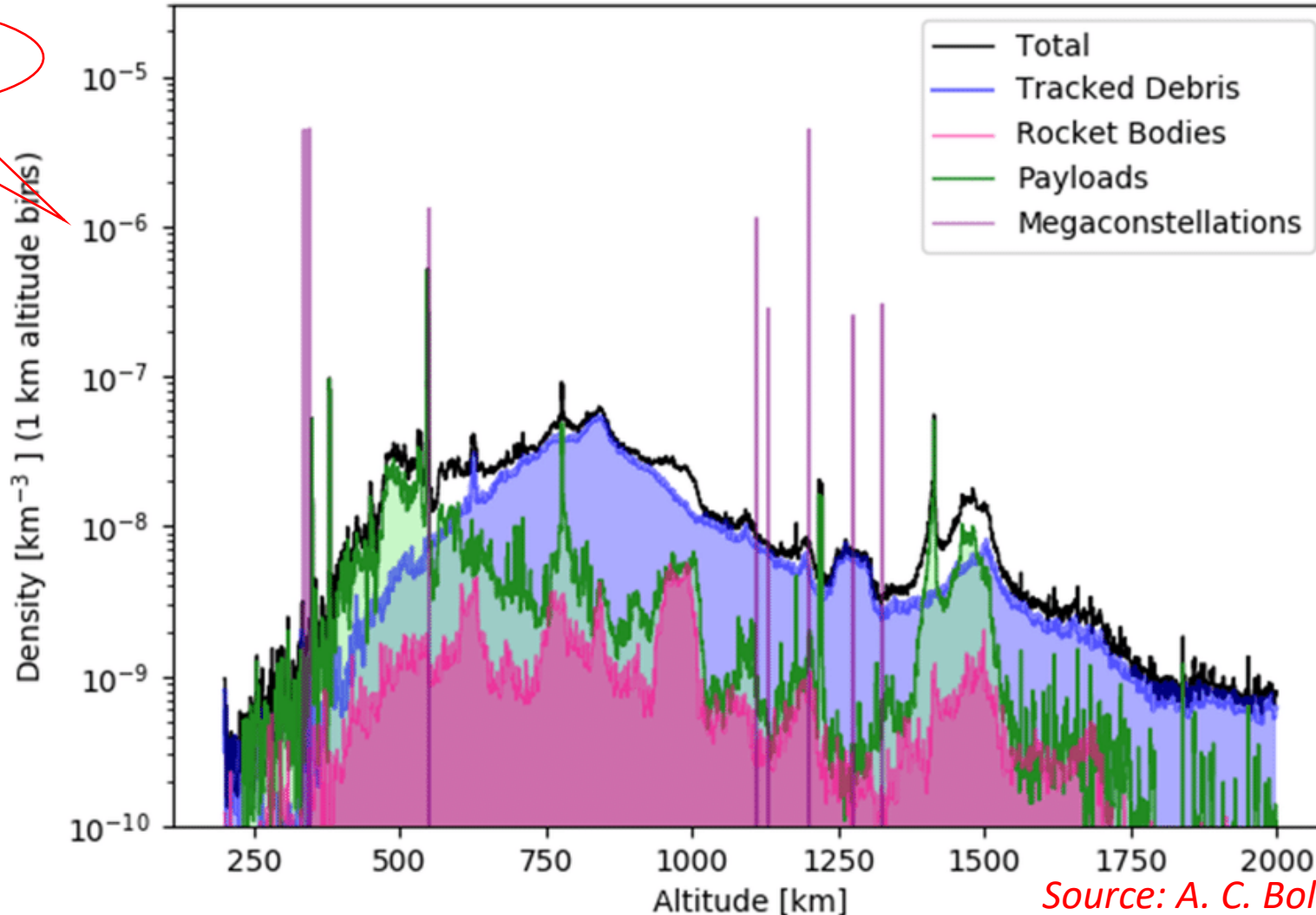
- Spectral interference (Ku & Ka Bands*) with terrestrial networks (see the latest litigation between TIM & Starlink)
- The accumulation of space debris due to satellites replacement every 5 years may impact security of the atmosphere. With the anticipated emergence of Mega Constellations such as Starlink, OneWeb, Kuiper, Quinfan, Quowang, and IRIS2. we may well reach 500,000 satellites in the low earth atmosphere in the next 15 years
- Damages to astronomy investigations caused by light reflections due to the satellite crowd in the low earth atmosphere
 - *Ka band: 18-20 GHz downlink, 27.5-30 GHz uplink – Ku band: 10.7-12.7 GHz down, 14-14.5 GHz up*
 - *FCC E band: 71-76 GHz downlink e 81-86 GHz uplink*



LEO Satellite Density Distribution

Starlink & One Web, as filed with FCC

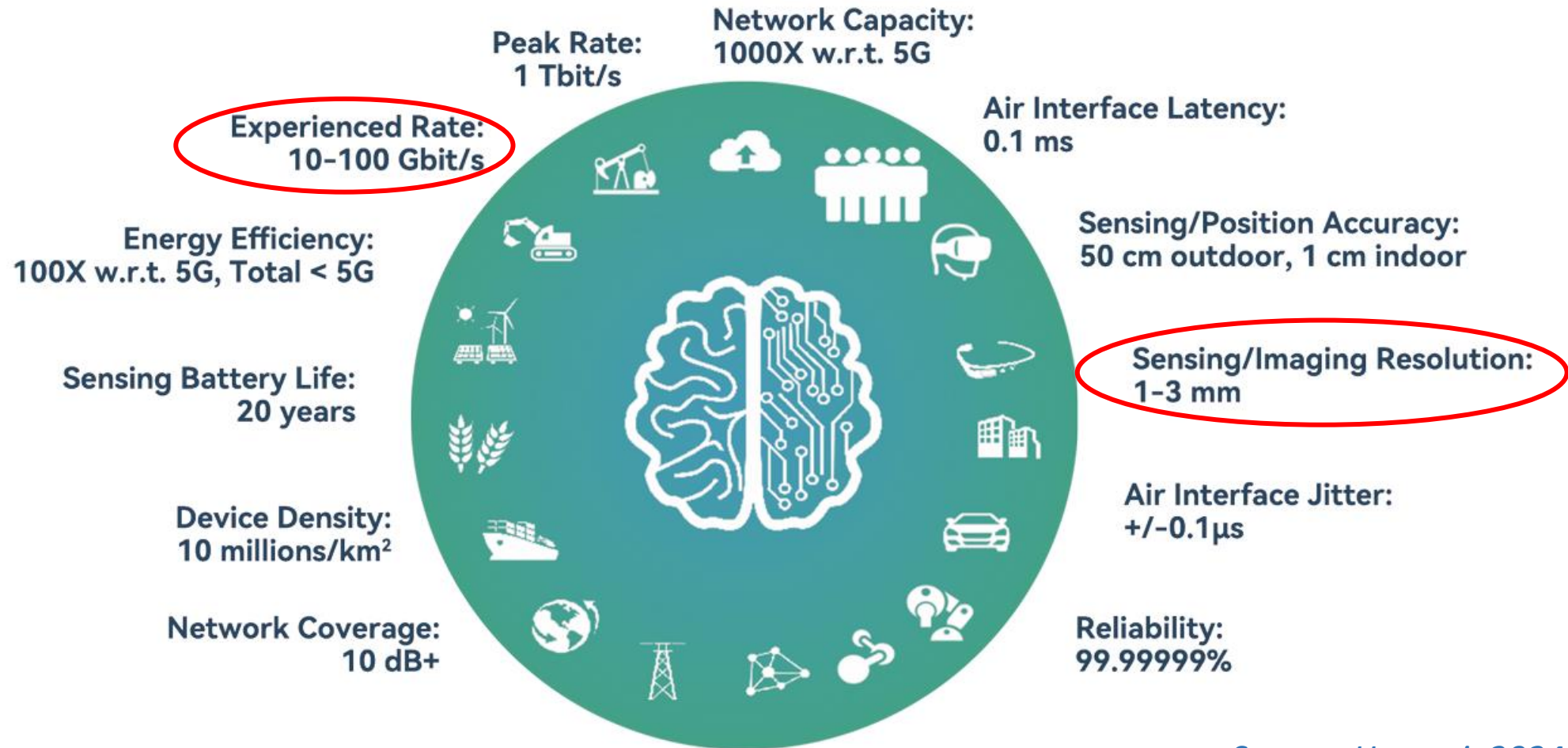
High Risk Threshold



Source: A. C. Boley & M. Beyers, 2021



6G Sensing & Communication (RAN KPIs)



Source: Huawei, 2024