



Above the Clouds & Below the Orbit: A Sustainable Future with High-Altitude Platform Stations



Mohamed-Slim Alouini

6G is Coming

Vehicle-to-everything



E-Health



Extended Reality



Super eMBB

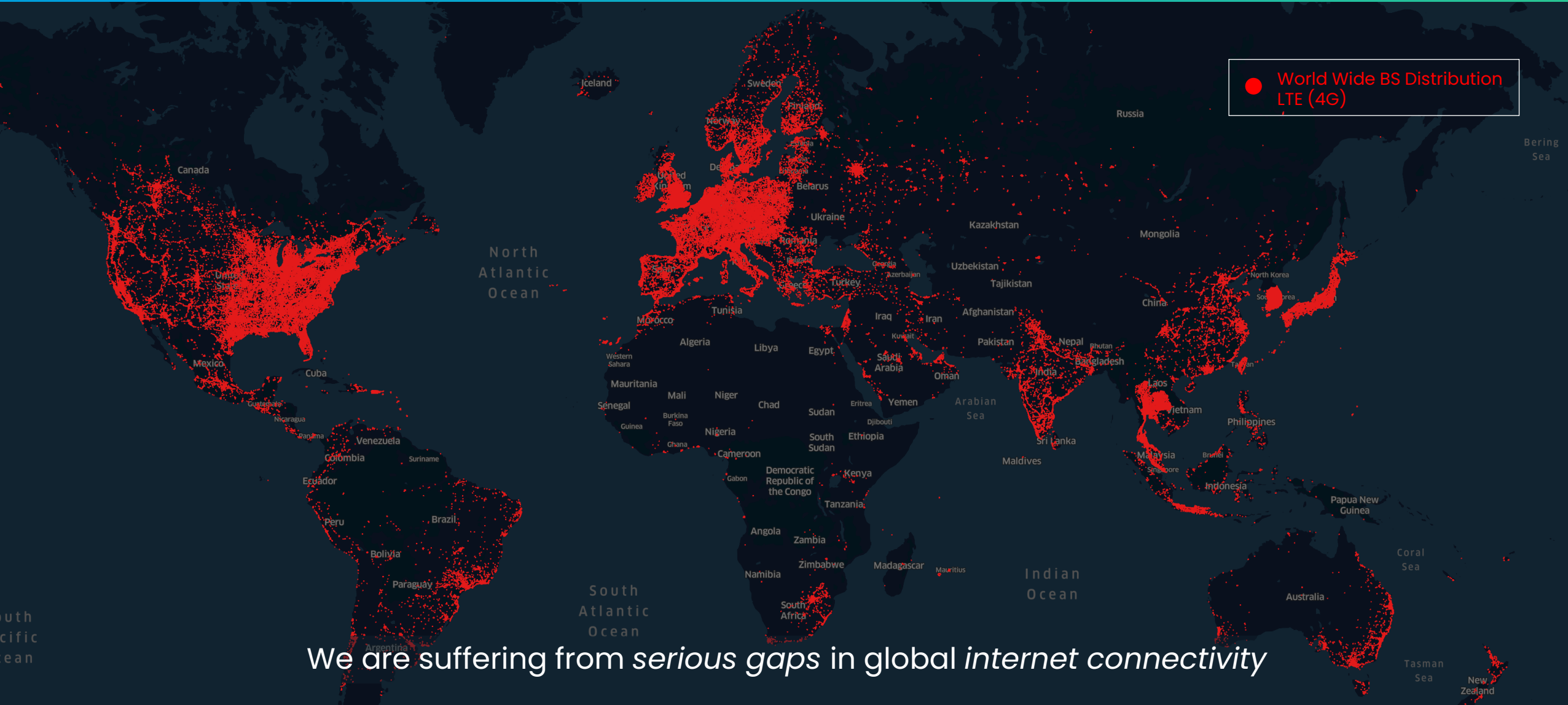


Artificial Intelligence

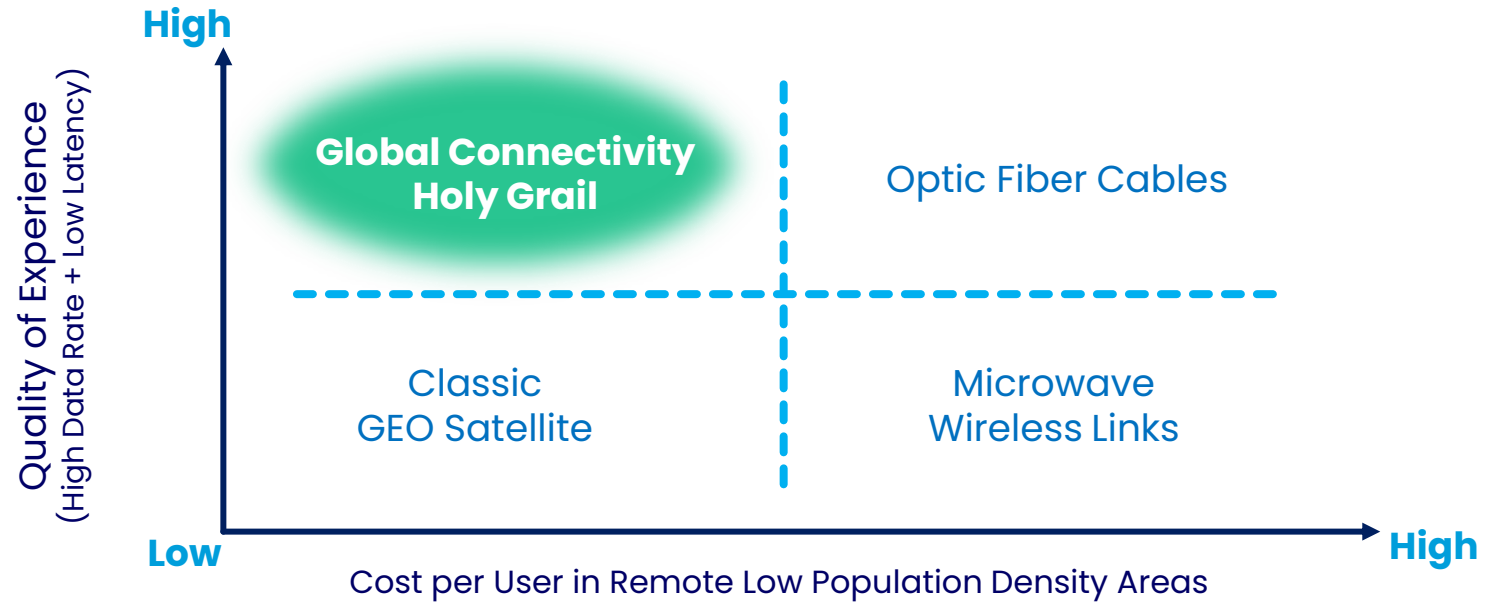


Industrial IoT





E. Yaacoub and M.-S. Alouini, "**A Key 6G Challenge and Opportunity - Connecting the Base of the Pyramid: A Survey on Rural Connectivity**", Proceedings of IEEE, 2020.



*A telephone subscriber here may call up and talk to any other subscriber on the **Globe**. An **inexpensive** receiver, not bigger than a watch, will enable him to listen **anywhere**, on **land** or **sea**, to a speech delivered or music played in some other place, however **distant**.*

— Nikola Tesla 1919

Disasters

Exploration

Military Mission

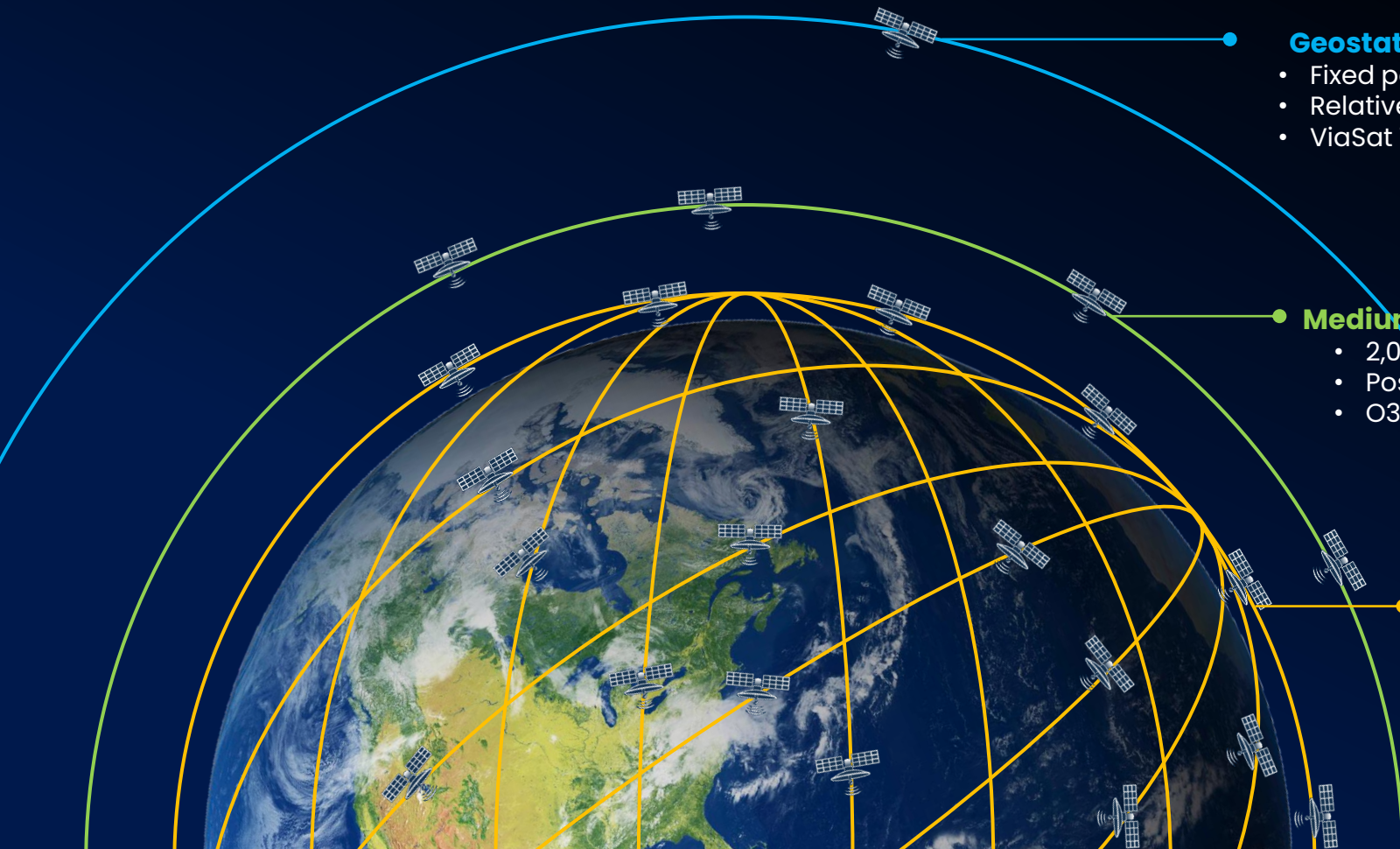
IoT Everywhere

Special Events

**Urban Aerial
Mobility/Aeronautical**

Maritime

Manufacturing Cost Down => Mass Production



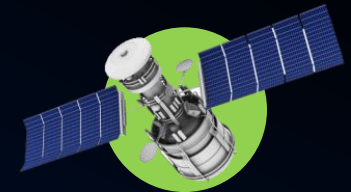
Geostationary Earth Orbit (GEO) Satellite

- Fixed position in the sky at ~35,000 km
- Relatively large delay
- ViaSat 1, 2, 3



Medium Earth Orbit (MEO) Satellite

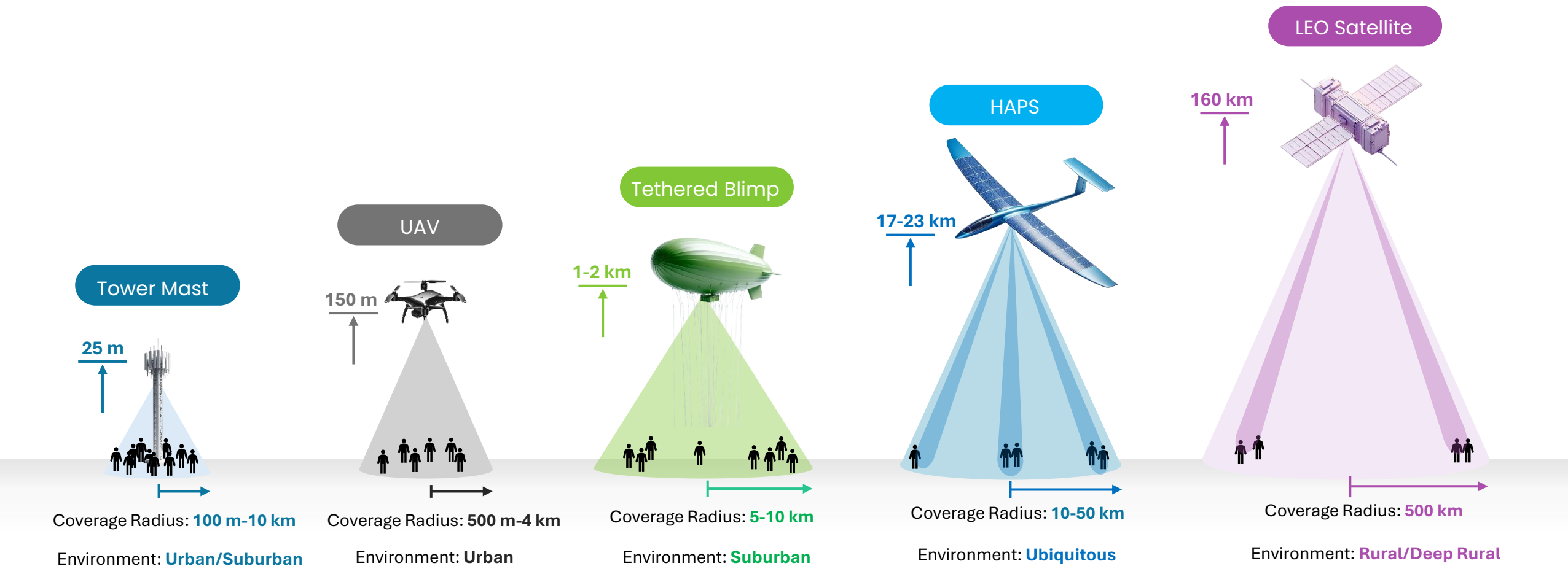
- 2,000~35,000 km
- Position and tracking
- O3B, SES Networks



Low Earth Orbit (LEO) Satellite

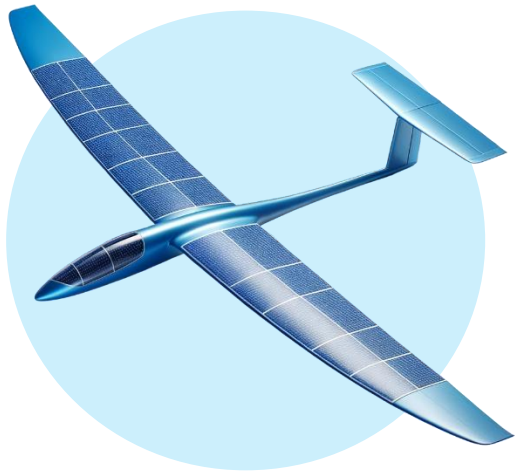
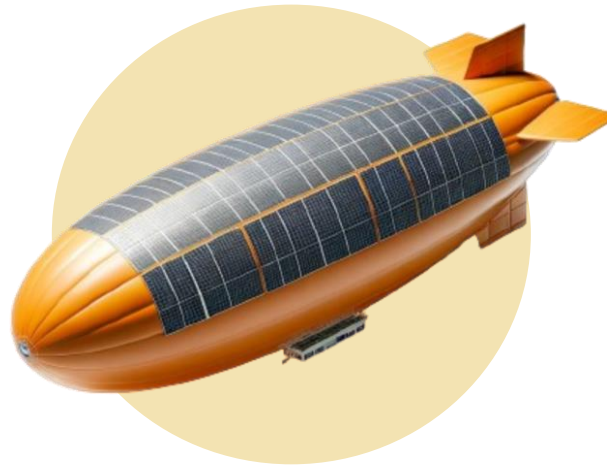
- 160~2,000 km
- Hand-Over
- OneWeb, Starlink, Lightspeed, Kuiper, GW, G60



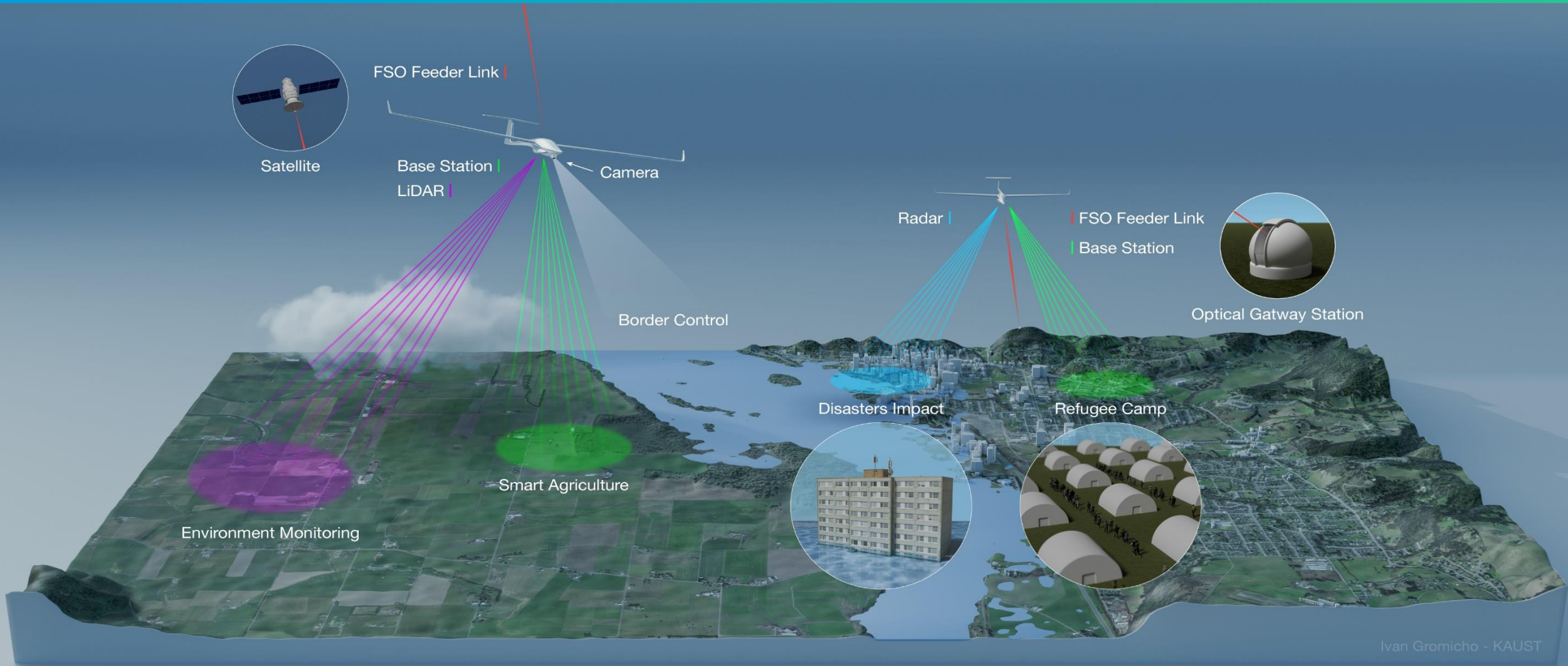


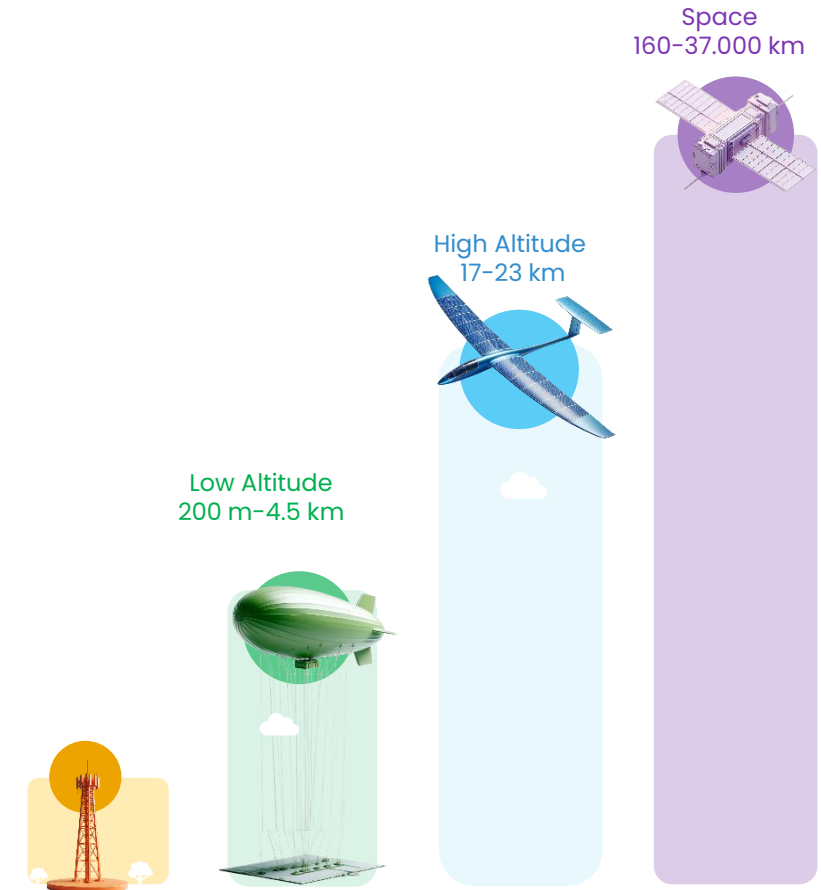
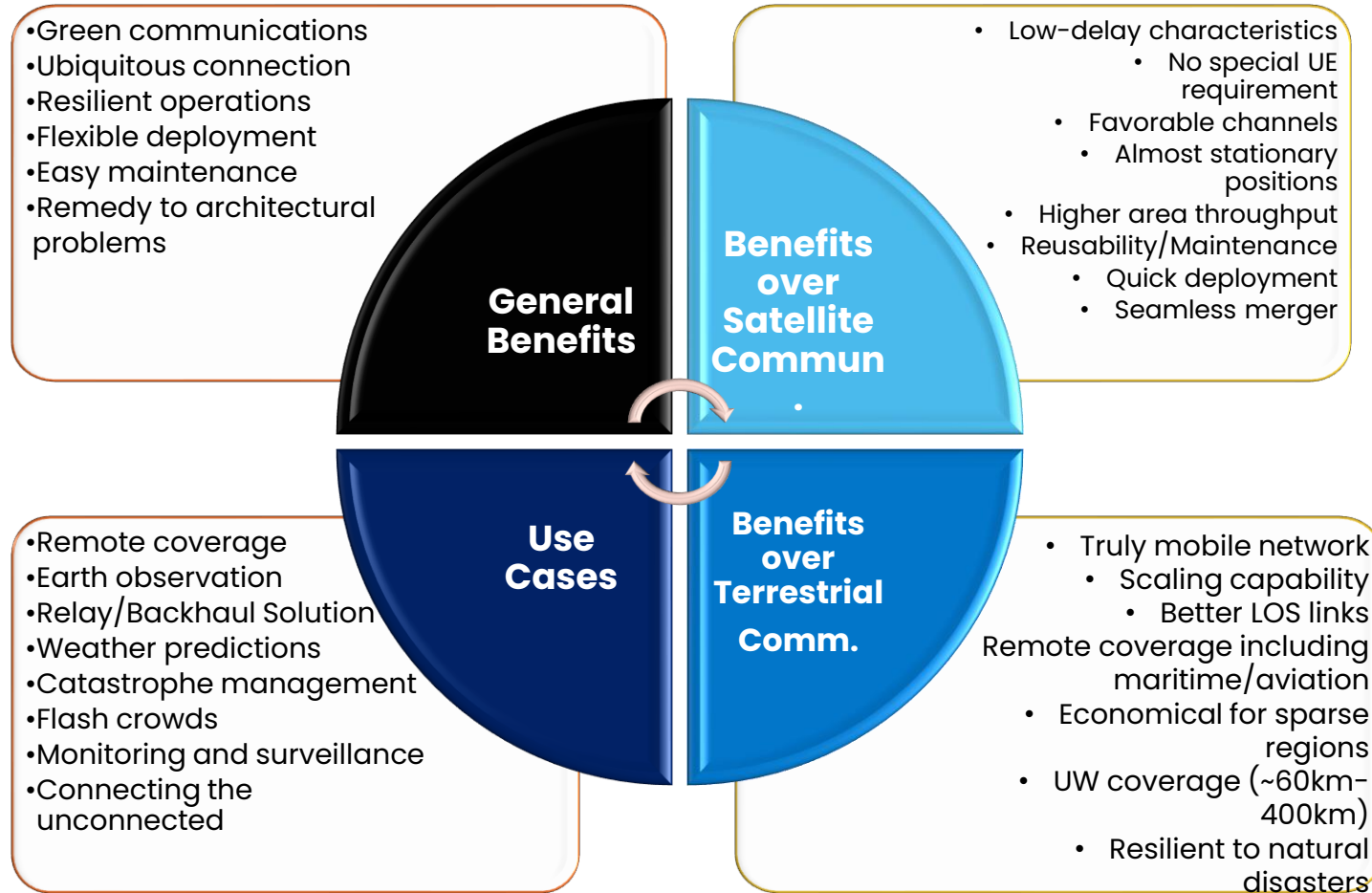
A wide-angle photograph taken from a high altitude, likely from a stratospheric balloon or aircraft. The view shows a vast, undulating desert landscape with golden sand dunes in the foreground. In the middle ground, a small, rectangular urban area with a grid-like street pattern is visible, surrounded by more desert. The horizon is a sharp line separating the land from a deep blue sky filled with wispy white clouds. A bright sun is visible on the left side of the horizon, creating a lens flare and illuminating the scene. A small, sleek, white aircraft with long, thin wings is flying across the upper portion of the sky, leaving a faint trail.

Stratospheric Based Stations

**Fixed-Wing****Airship****Balloon**

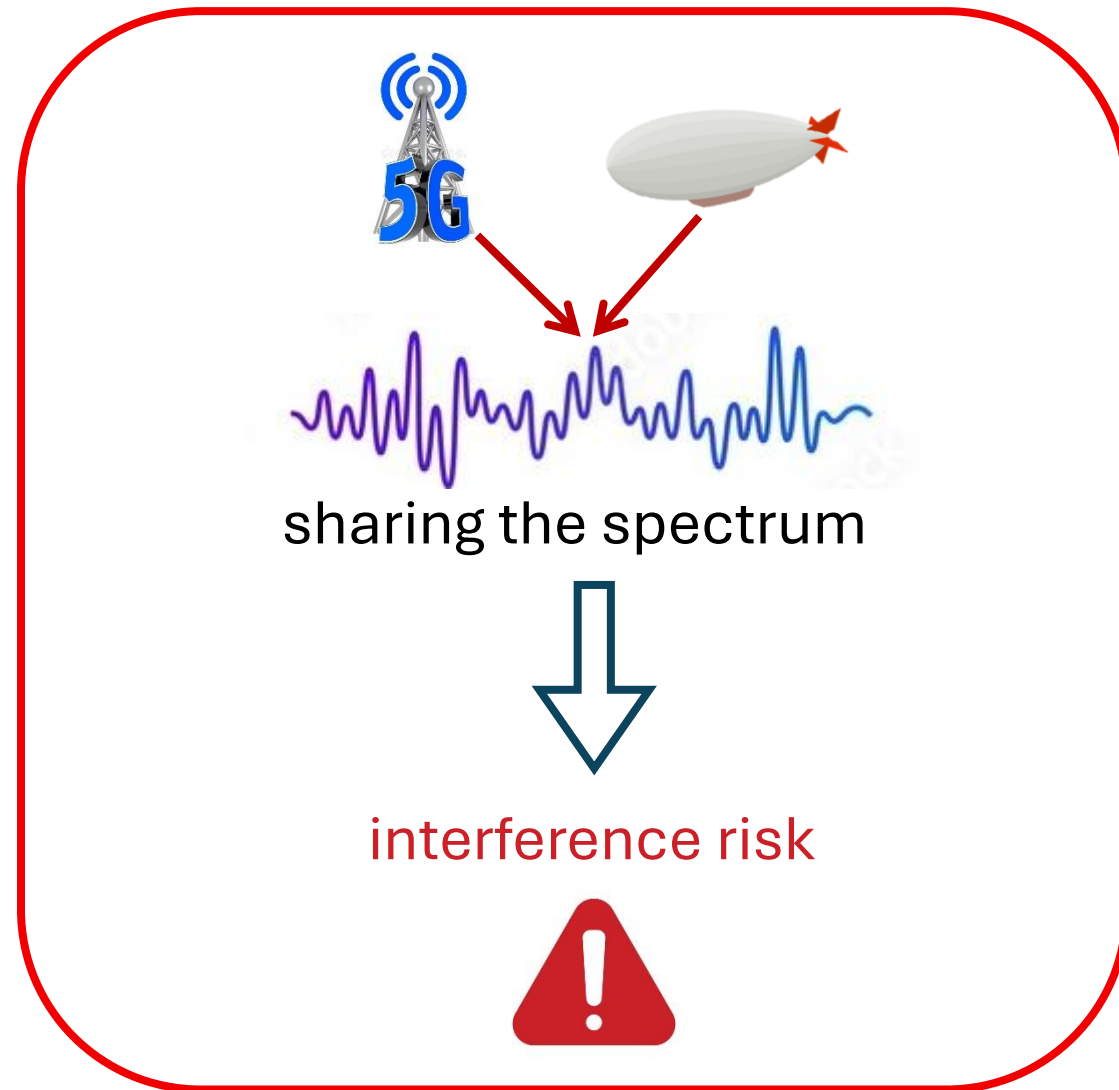
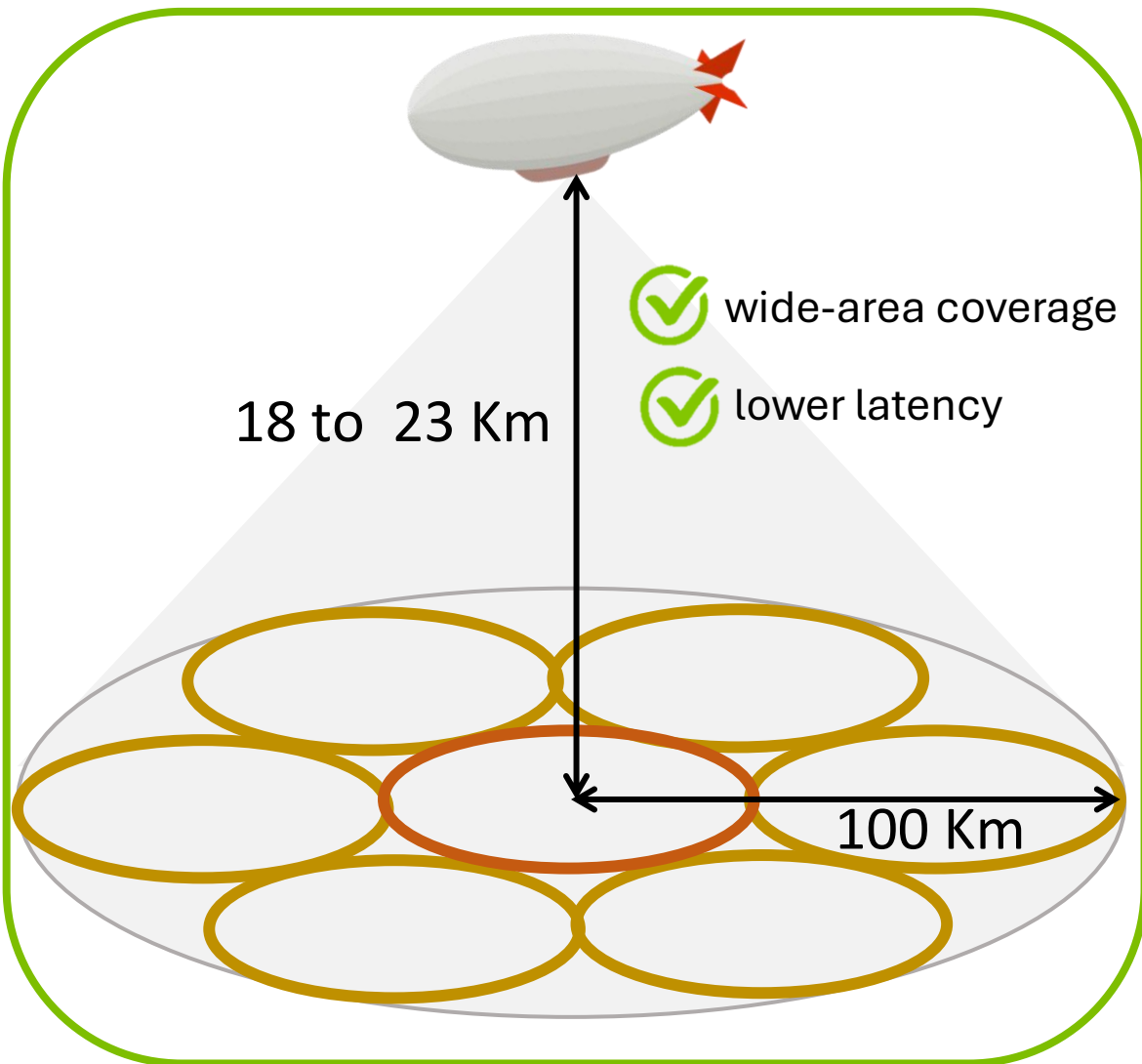
HAPS with Multiple Missions



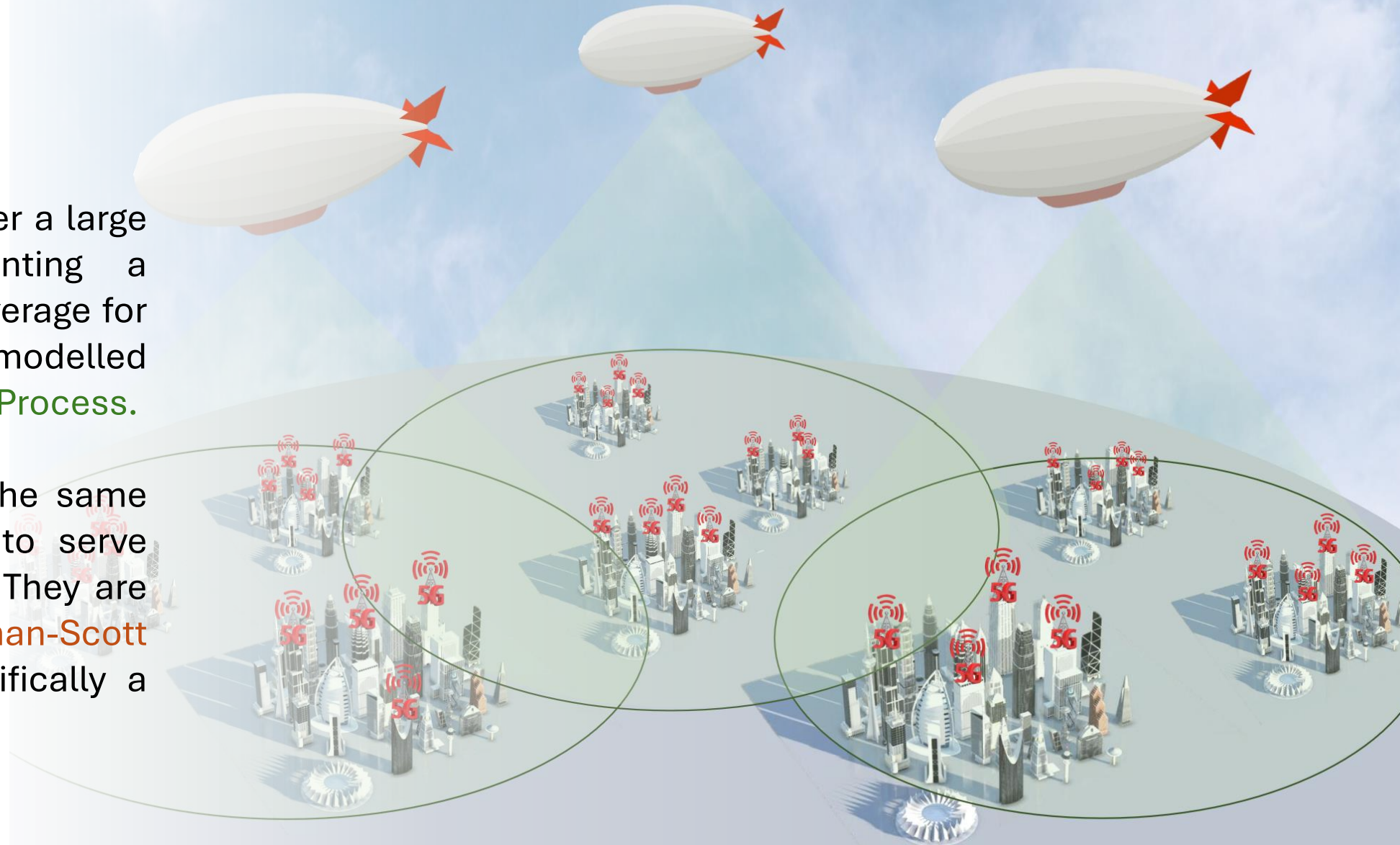




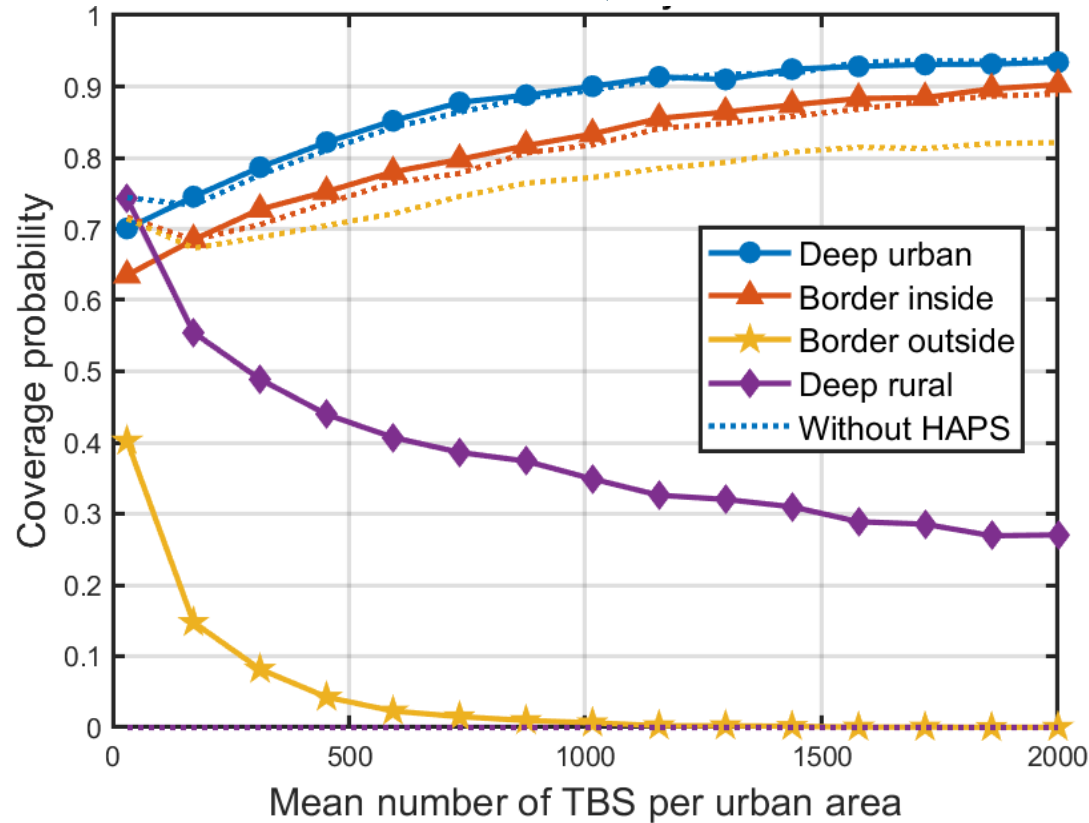
Coexistence of HAPS and Terrestrial Networks



- **HAPS** are deployed over a large geographical representing a country, to provide coverage for **rural regions**. They are modelled as a **Matern Hard-core Process**.
- **TBS** are deployed in the same area but specifically to serve **urban regions** (cities). They are modeled using a **Neyman-Scott cluster process**, specifically a Matern cluster process

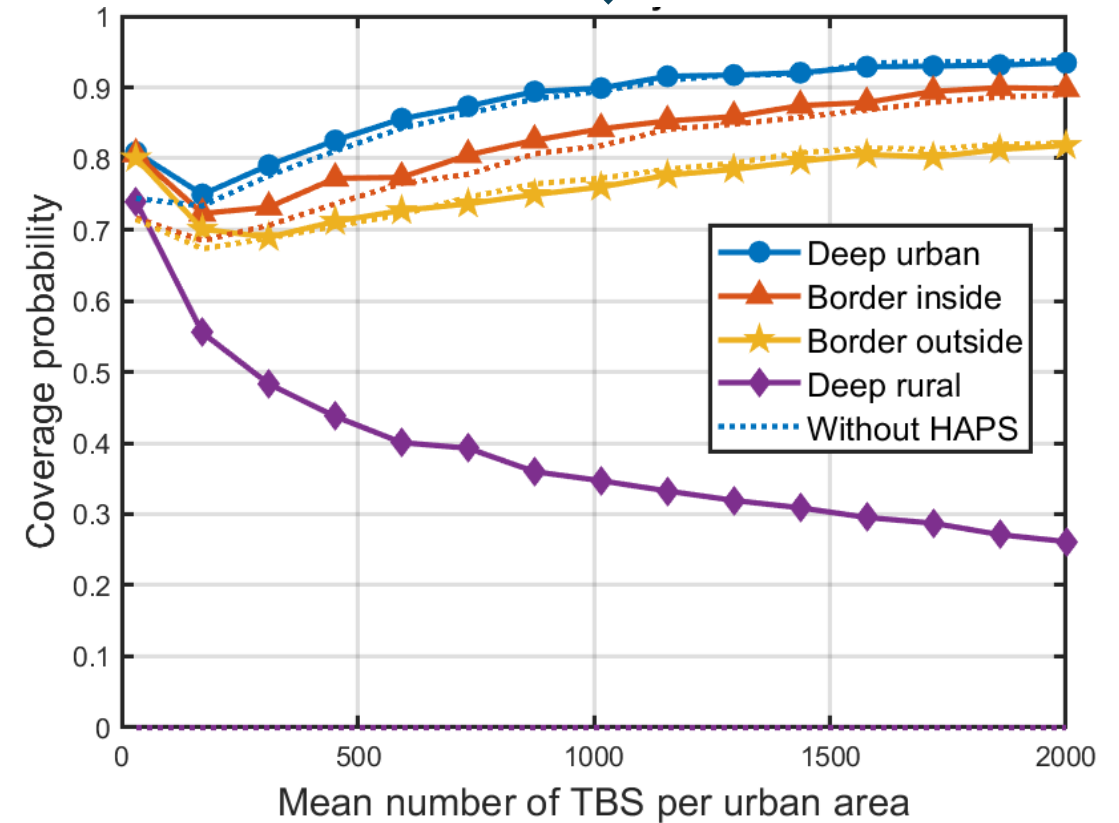


Uncoordinated Systems



- Uncoordinated operation highlights the vulnerability of rural coverage to interference coming from 5g network

Coordinated Systems

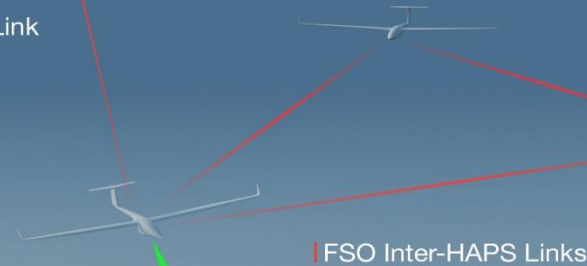


- Coordinated operation demonstrates the potential to optimize performance through adaptive association policies



Satellite

FSO Feeder Link



FSO Inter-HAPS Links

RF Access Links

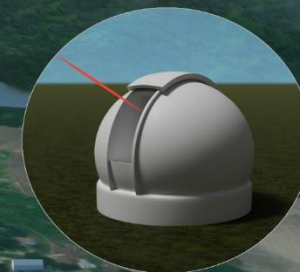
FSO Feeder Link



Mobile User



IoT Devices



Optical Gateway Station

Ivan Gromicho - KAUST

- HAPS offer **local coverage with a global mindset**
- Satellite mega-constellations risk **orbital crowding and debris** vs. HAPS stay in the stratosphere and can be recovered or reused.
- Hybrid networks (HAPS + Satellites) can deliver resilience **without sacrificing sustainability**.
- Sustainable skies are not optional → they are the **foundation of a responsible digital future**.



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Thank You

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