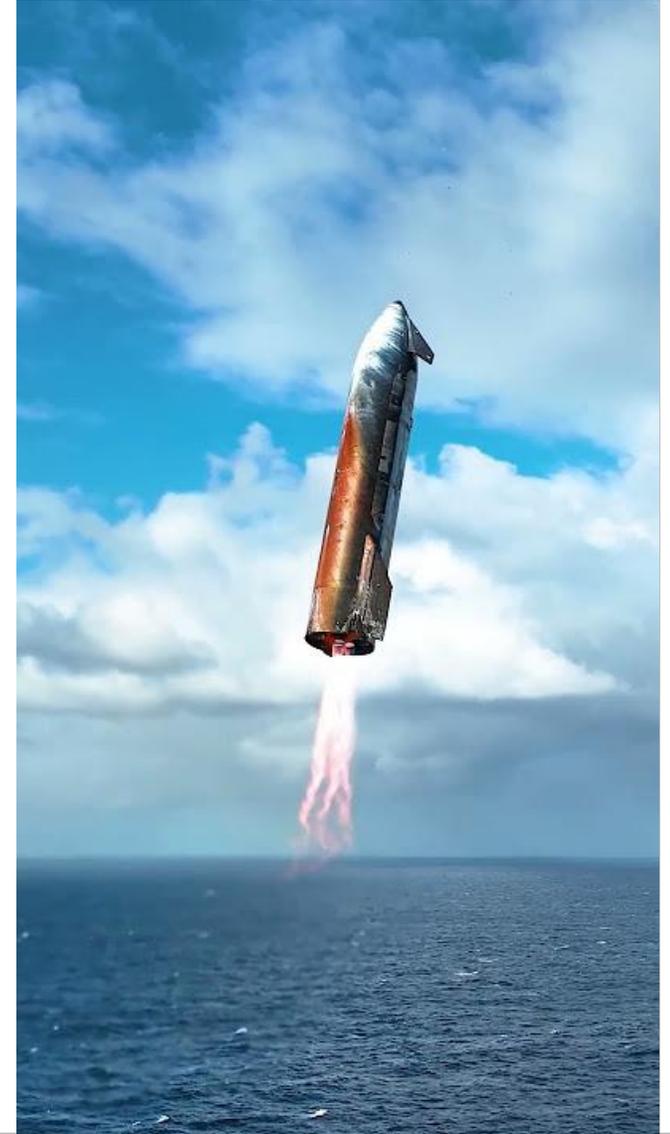
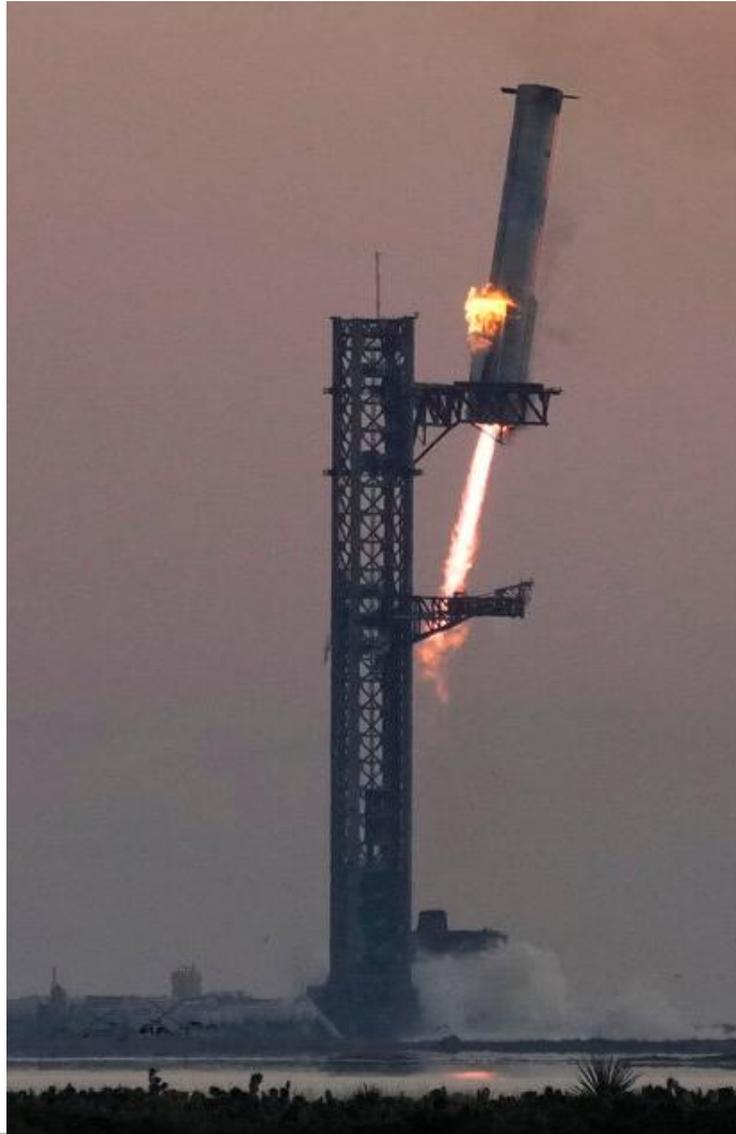


Laser Comms: The Missing Link to Connect Earth... and Space

Earth Observation, Quantum Key Distribution,
5G NTN, DTD, Orbital Data Centers,
and the Digital Divide

Jean-Edouard Communal, jec@miratlas.com

Reusability: lowering cost to orbit, kg/LEO/\$



Satellites launched annually

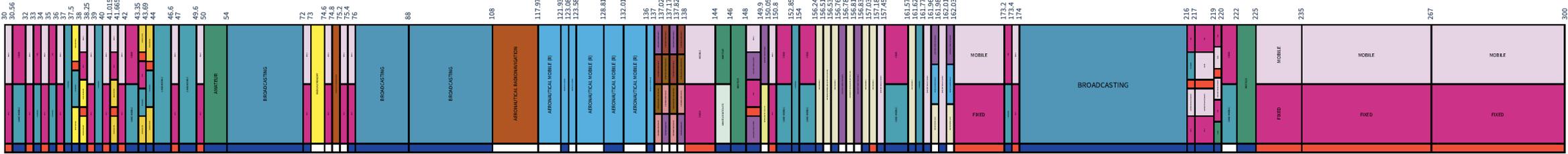


Radio Teleport

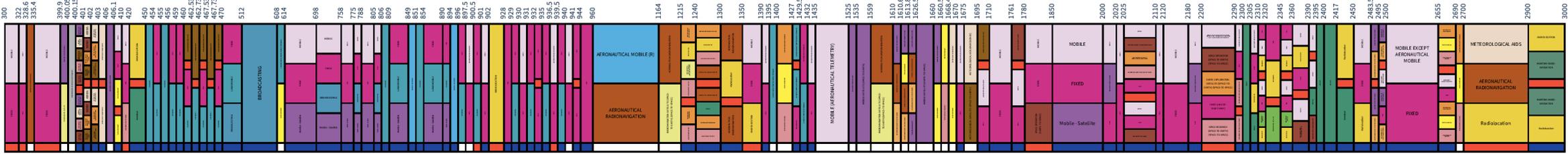




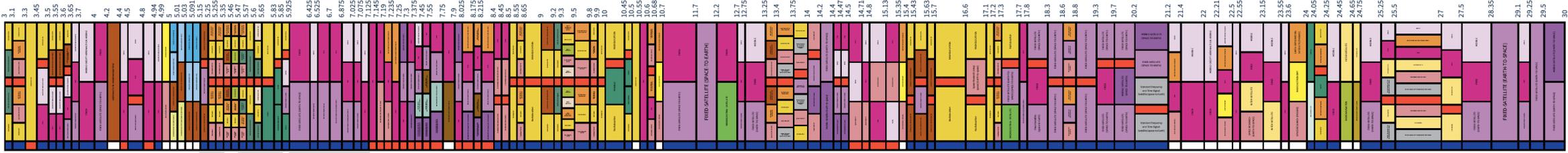
Radio Frequency Bottleneck



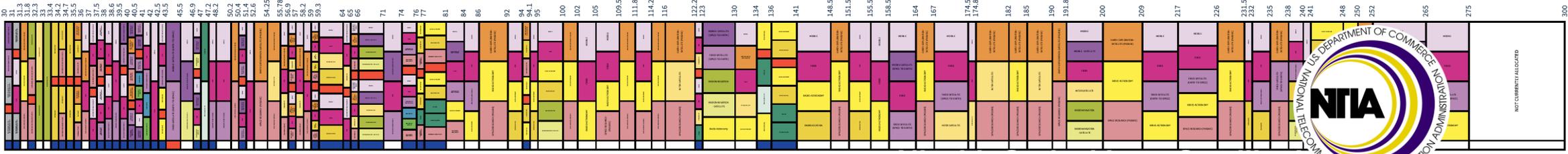
30 MHz



300 MHz



3 GHz



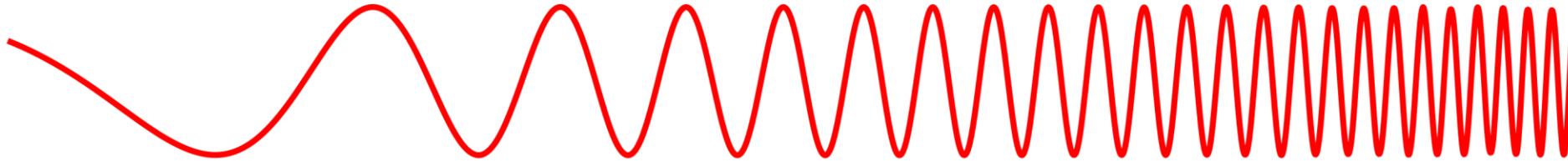
30 GHz



Electromagnetic Spectrum



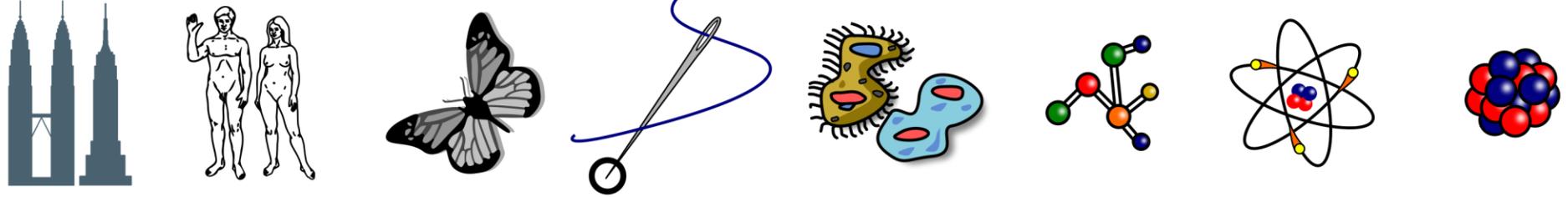
Penetrates Earth's Atmosphere?



Radiation Type
Wavelength (m)

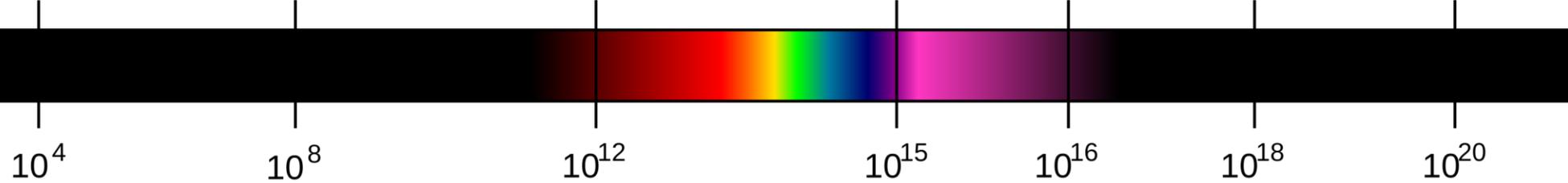


Approximate Scale
of Wavelength



Buildings Humans Butterflies Needle Point Protozoans Molecules Atoms Atomic Nuclei

Frequency (Hz)

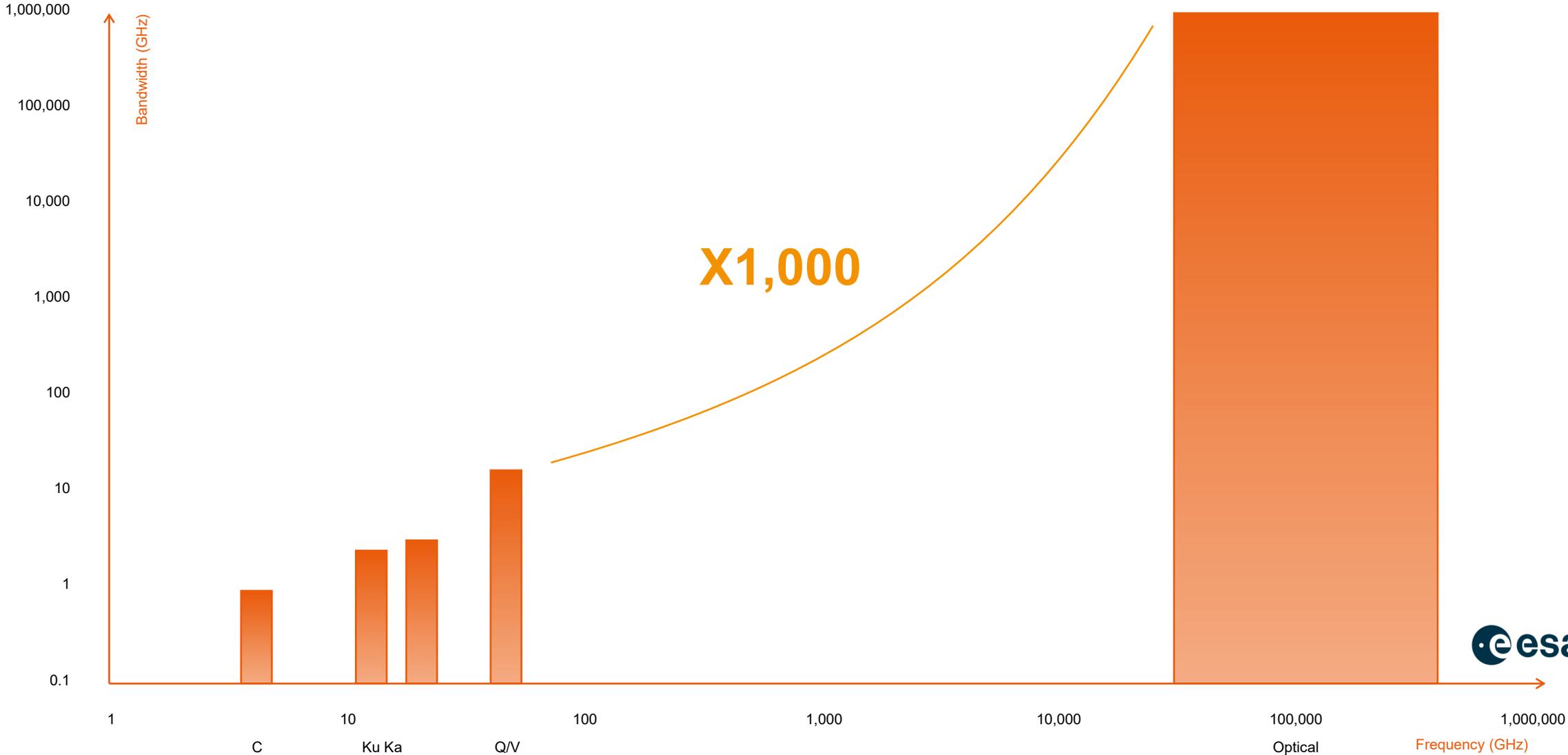


WIKIPEDIA

LaserCom today: Optical Inter Satellite Link, OISL



Laser Comms : lower backhauling cost, Mbps/user/\$



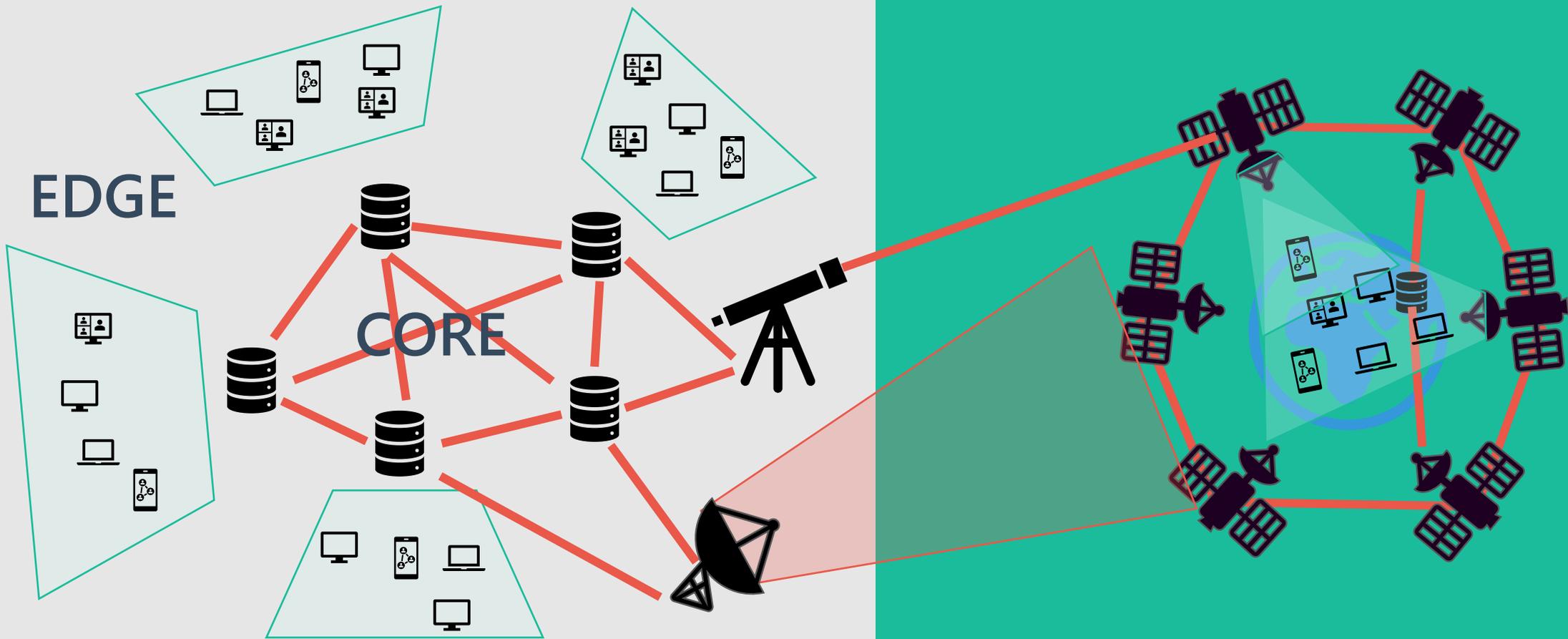
Optical Ground Station: Earth to Space LaserCom



Infrastructure convergence: optical core and radio edge

GROUND Network CORE

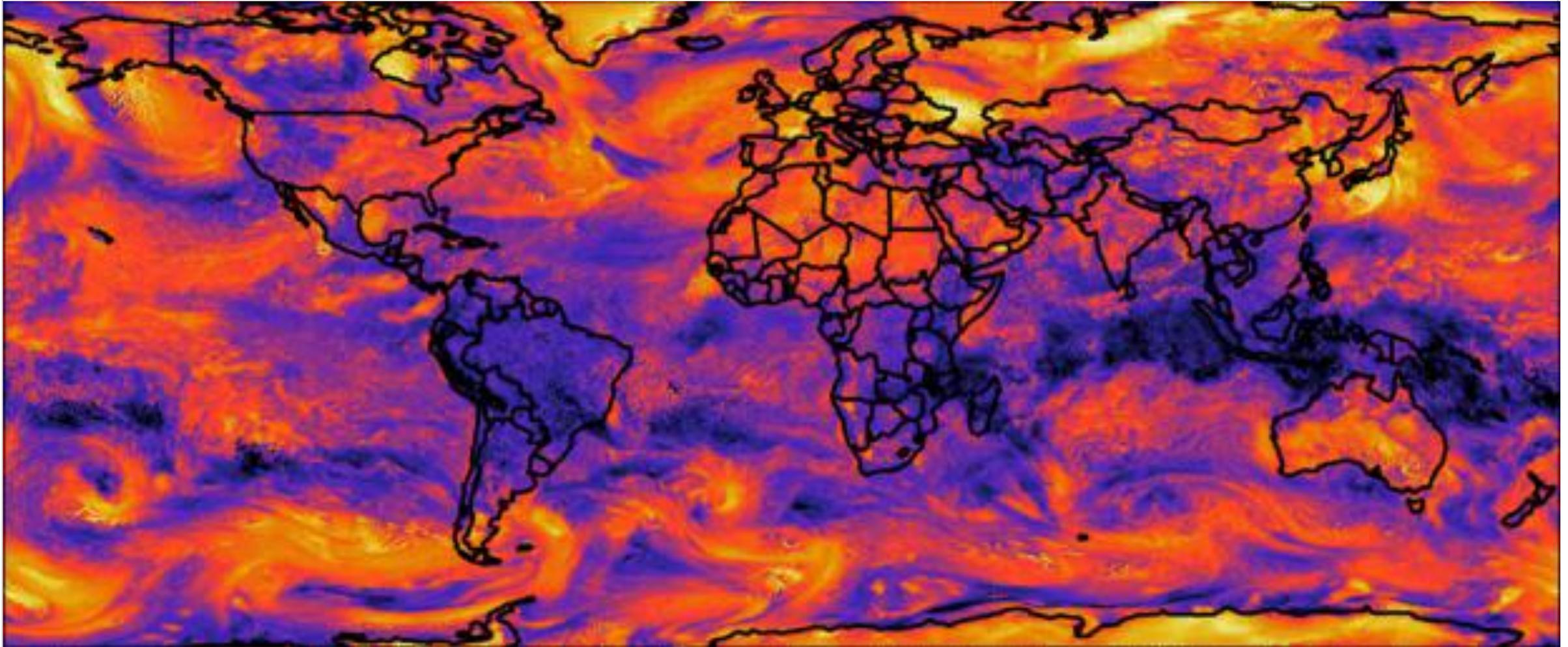
SPACE Network EDGE



Challenge: LaserCom Through the Atmosphere



Challenge: LaserCom Through the Atmosphere



Mitigation techniques to Atmospheric light propagation



Geographical **site diversity**

- Network planning & design

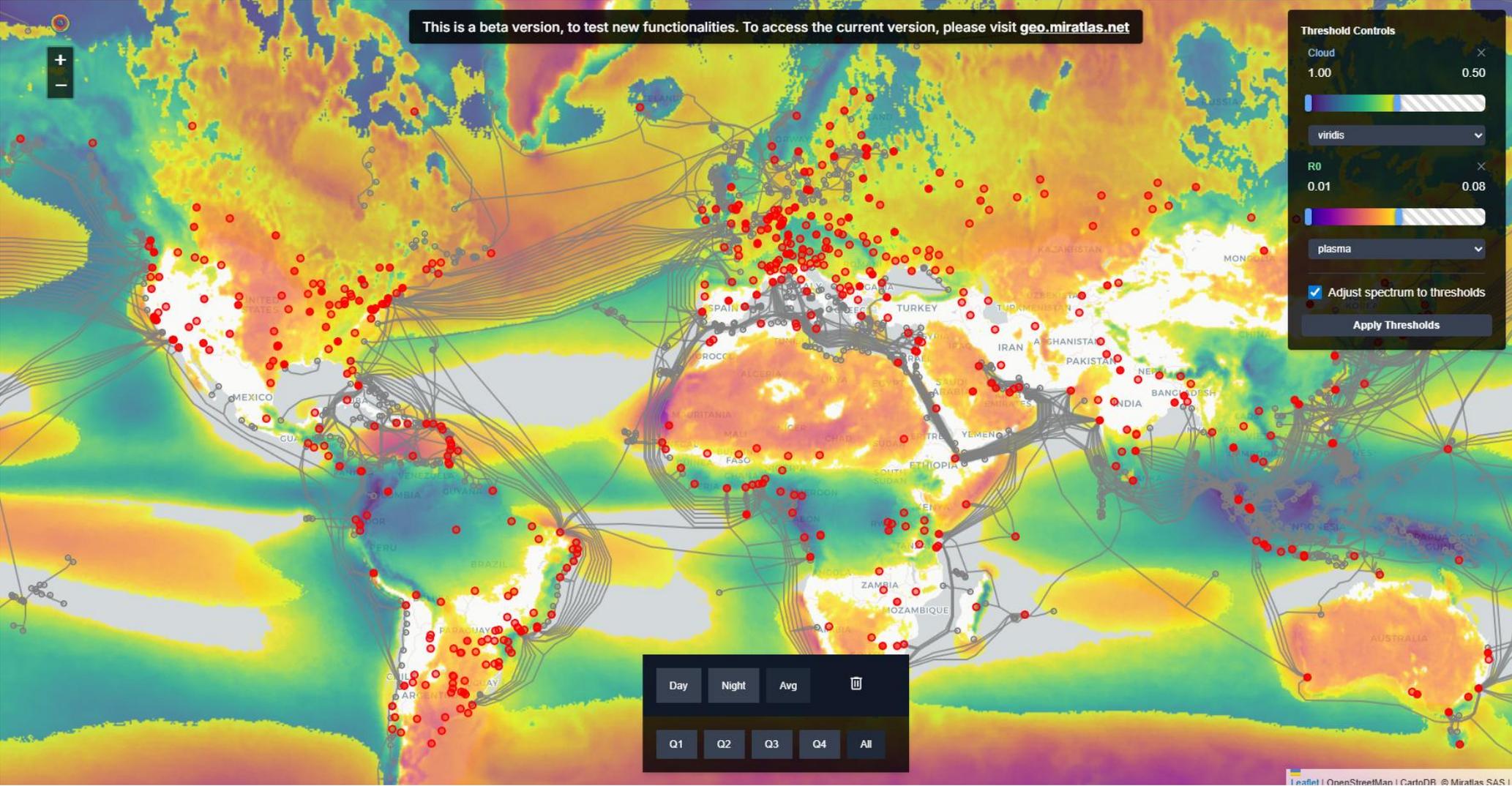
Turbulence correction

- **Adaptive Optics**, (Optical Ground Station)
- **Encoding**, interleaving, FEC (Modem)

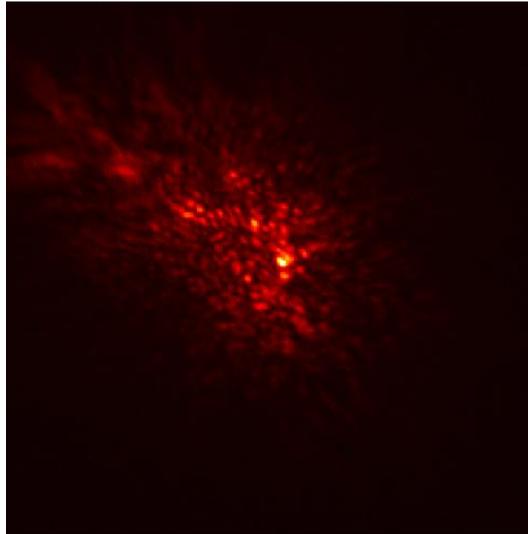
Dynamic **network routing**

- Network operations

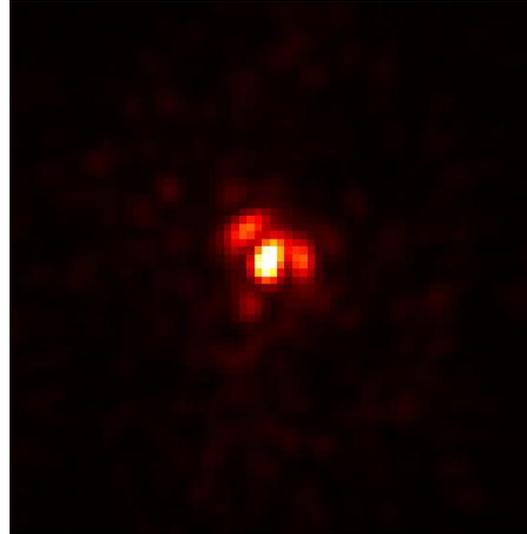
Geographical Site Diversity



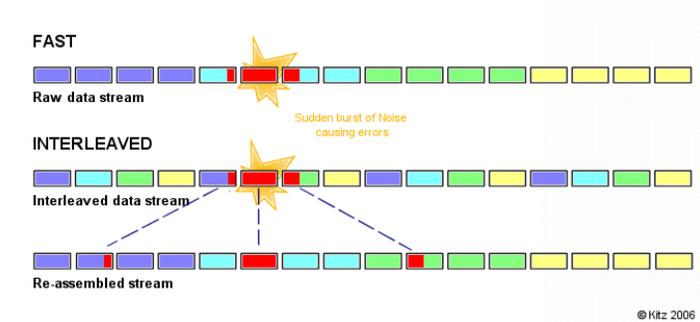
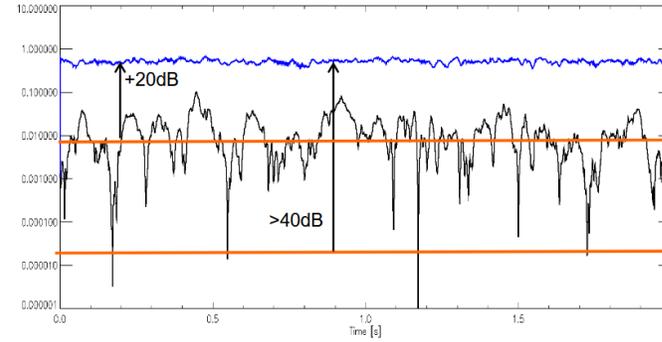
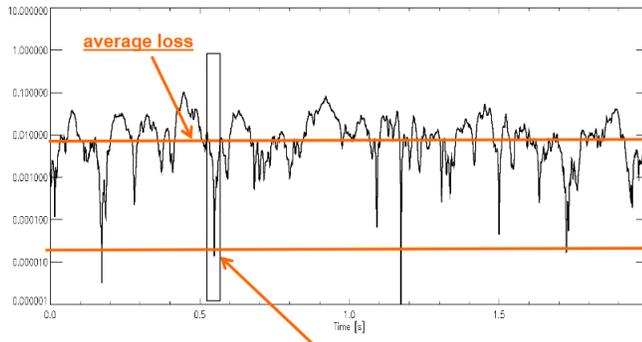
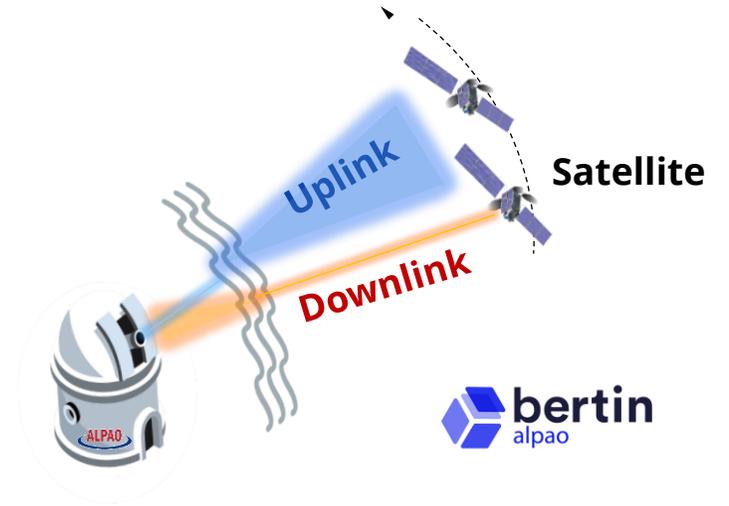
Turbulence correction: Adaptive Optics & Encoding



-40dB



-3dB



Network Operations & Routing



“ ” + + +

Space will be much more restrictive [in terms of] **frequencies and orbital slots**

Josef Aschbacher



“ ” + + +

The vast **majority of the cost** is in [...] the **ground segment**

[...], all those gateways you need to link back to the satellites around the Earth

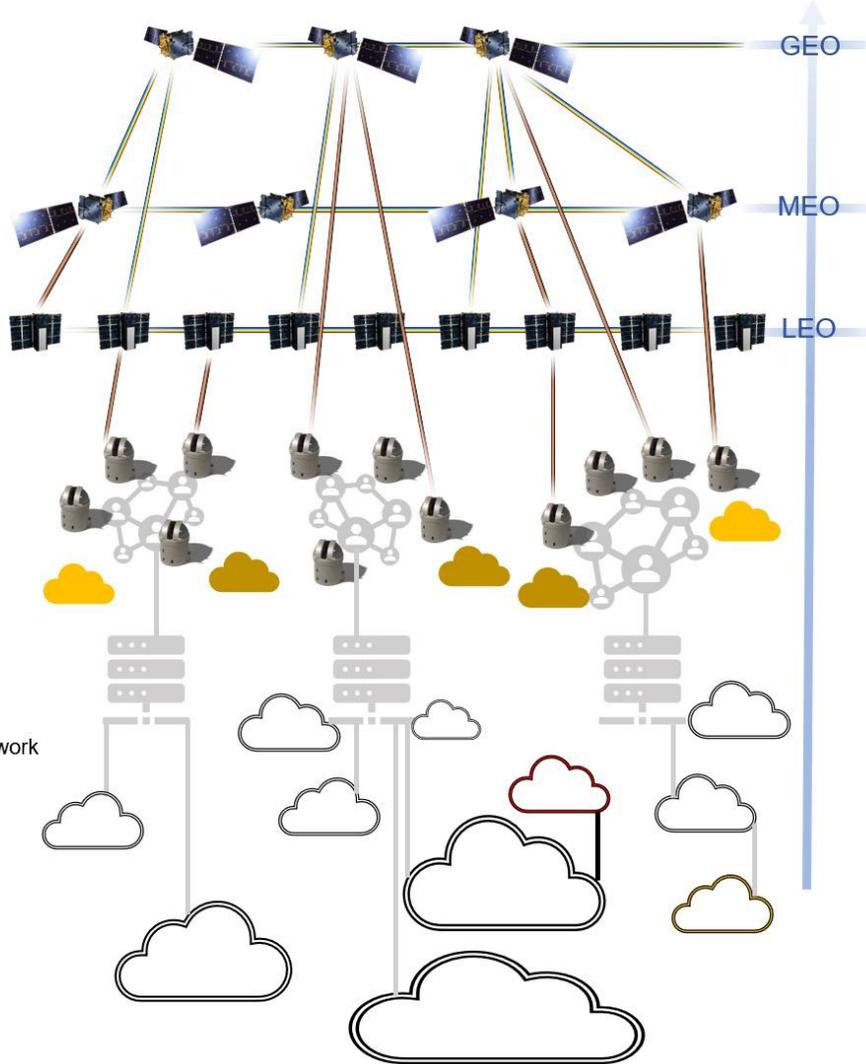
Tim Farrar



ESA SPECIFICATION FOR TERABIT/SEC OPTICAL LINKS (ESTOL) 09/10/2023



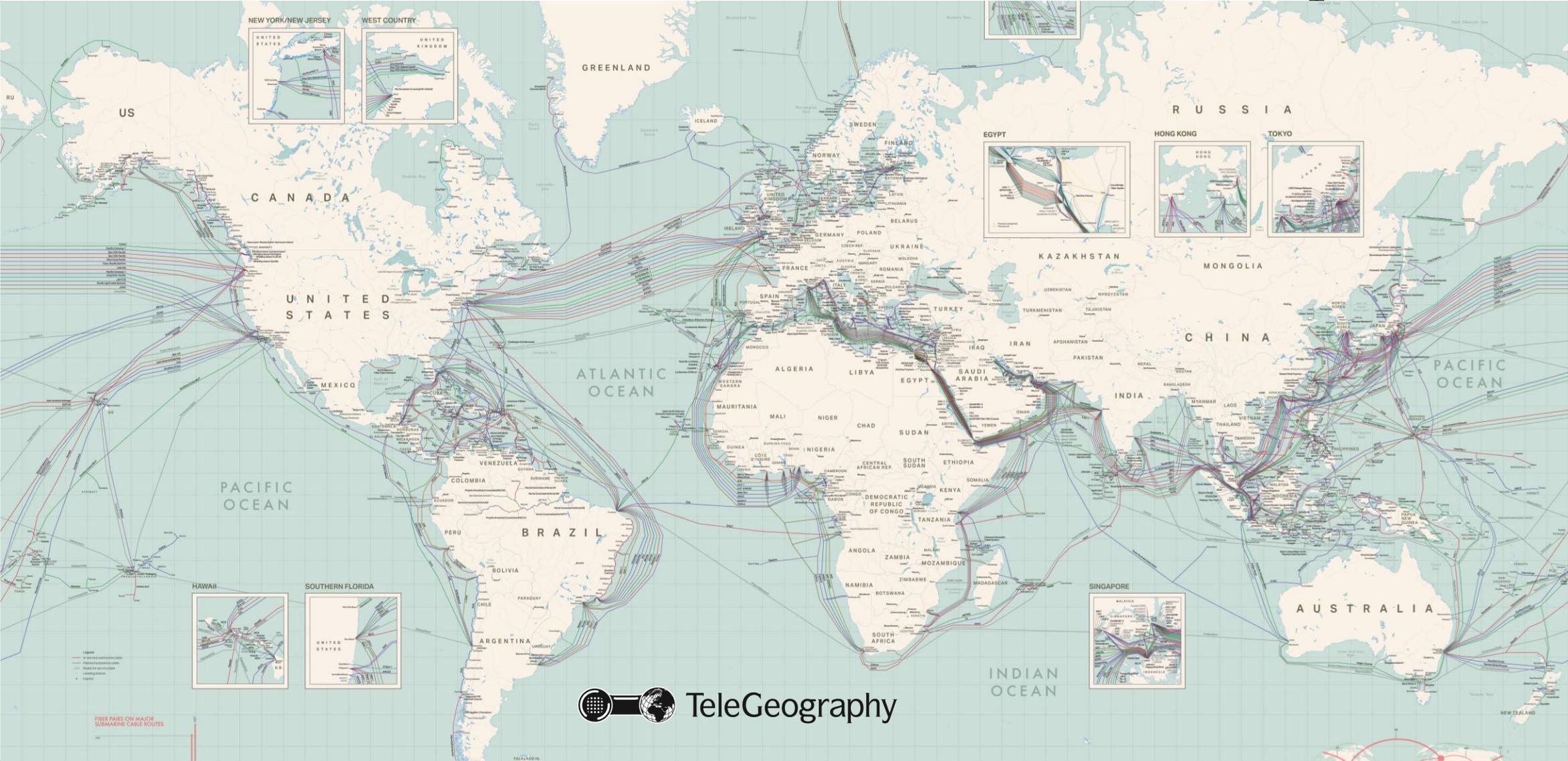
-  GEO core Node
-  LEO core Node
-  Optical Ground Station
-  IP exchange – network to network interface
-  Terrestrial Networks
-  Secure Networks
-  Private Networks
-  Ground Station network



Ground Infrastructure : Launch Sites



Ground Infrastructure : Optical Network



Solution: Reliable Direct-to-Earth LaserCom



1

Site Selection

+++

2

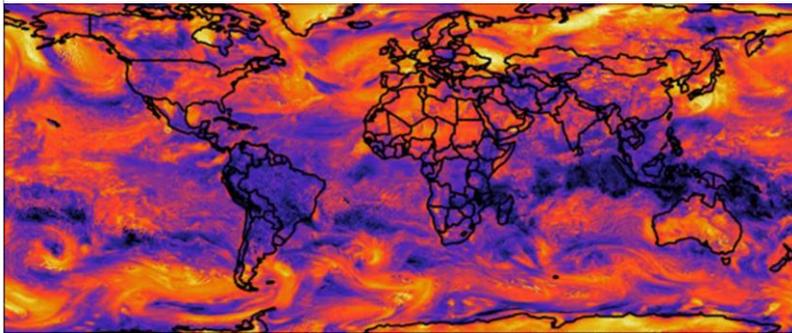
Network Planning

+++

3

Network Operations

+++



Global network accumulating **Seasonal data**



Atmospheric Channel **Forecasting**

Atmospheric **modelling**



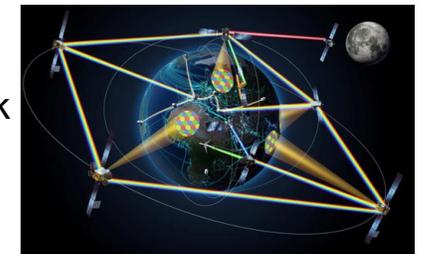
On site **measurements**



Optical Ground Station **Design**
Ground Segment **Deployment**

Historical & Real time **Atmospheric Data**

Dynamic Network **Routing**

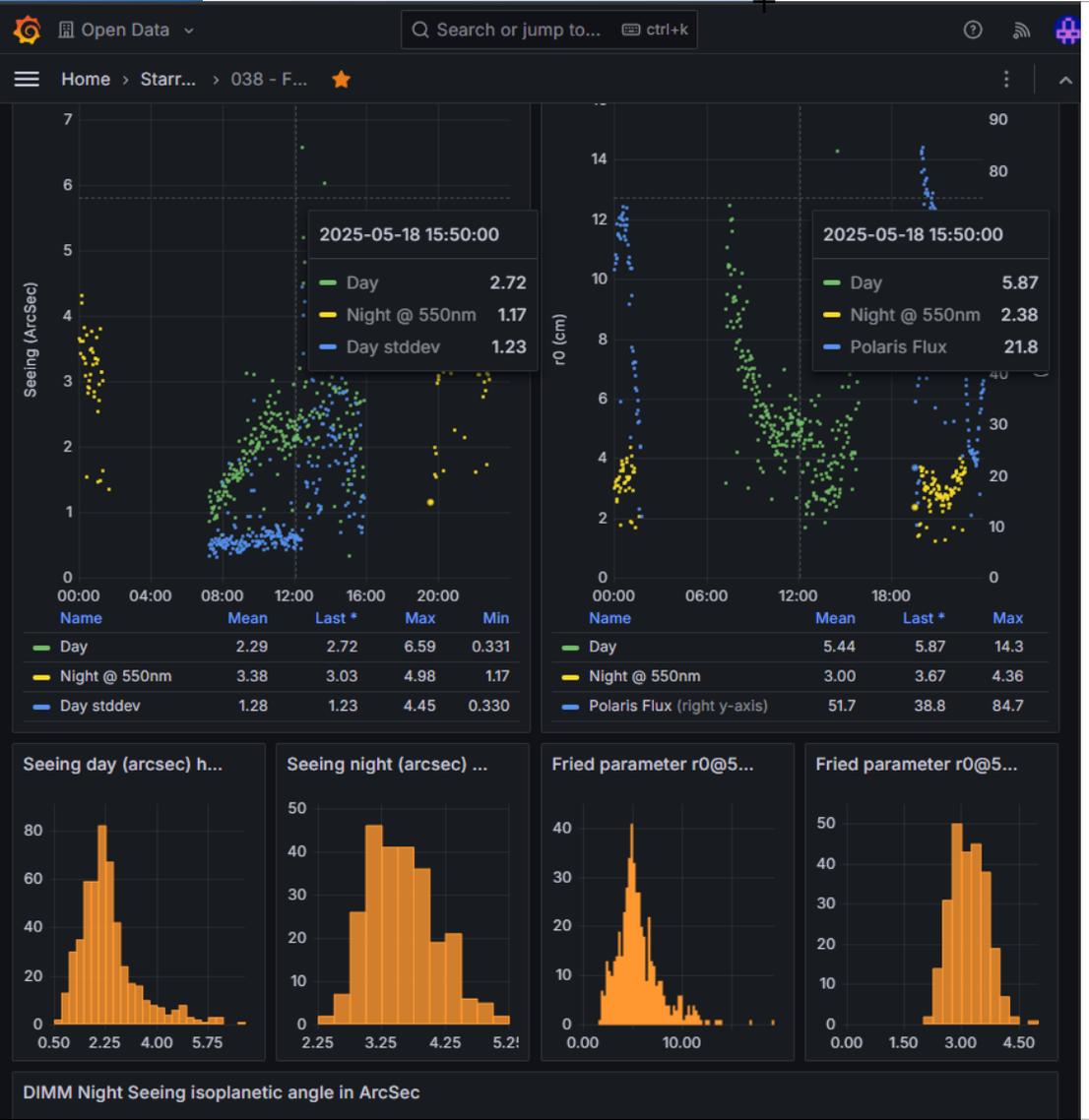
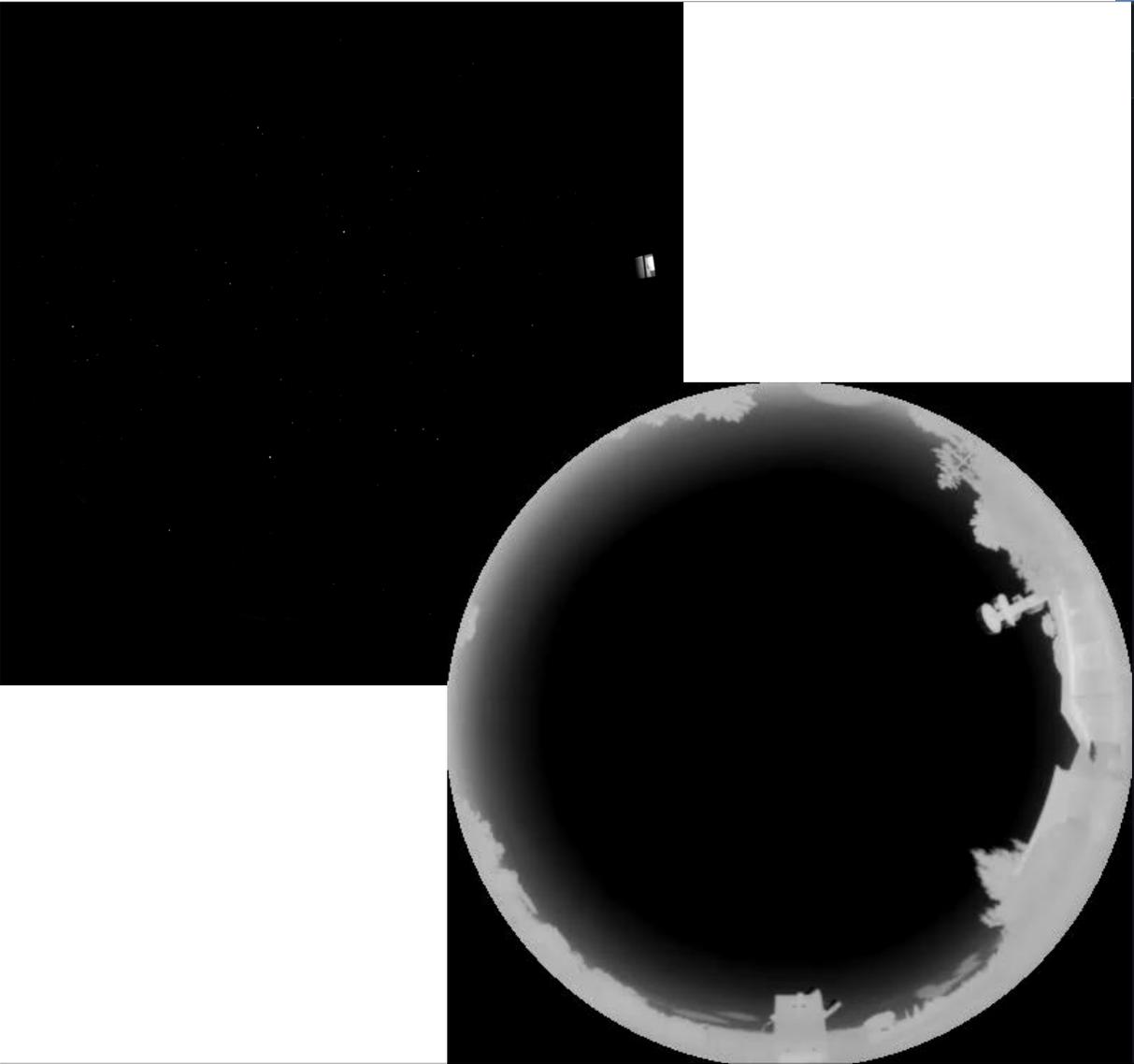


Forecasted Link **Availability & Budget**

Local Atmospheric Data

1

Site Selection



Lasercom global modelling

2

Network Planning

+++



Cloud Cover

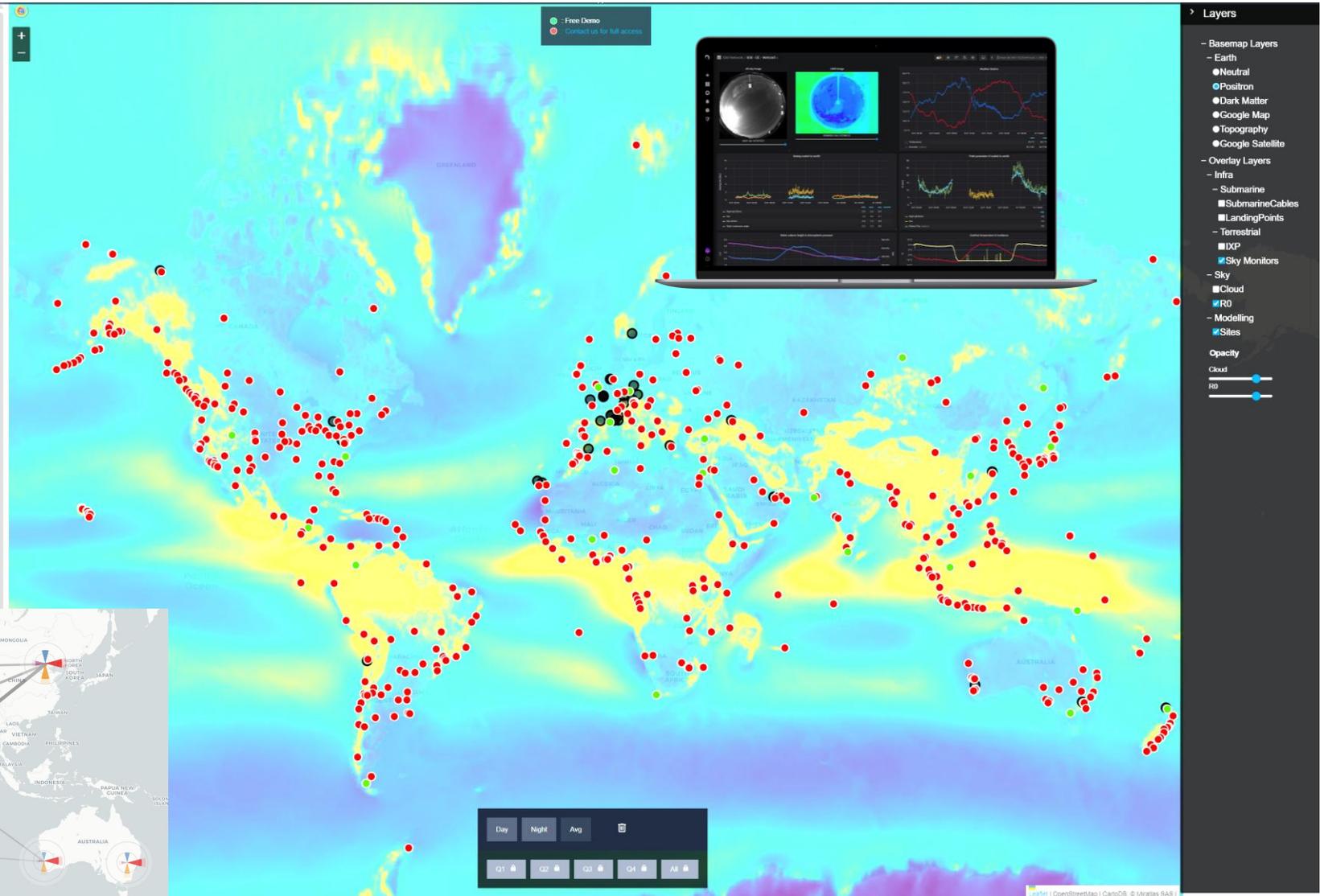
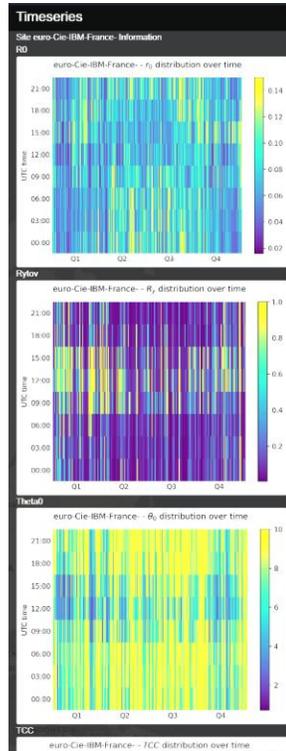
Total Cloud Cover
Distribution vs Time

Turbulence

r_0 , σ^2_r , θ_0 , τ_0

Temporal analysis

Decorrelation & Complementarity



Minimum Viable Network

3

Network Routing

+++

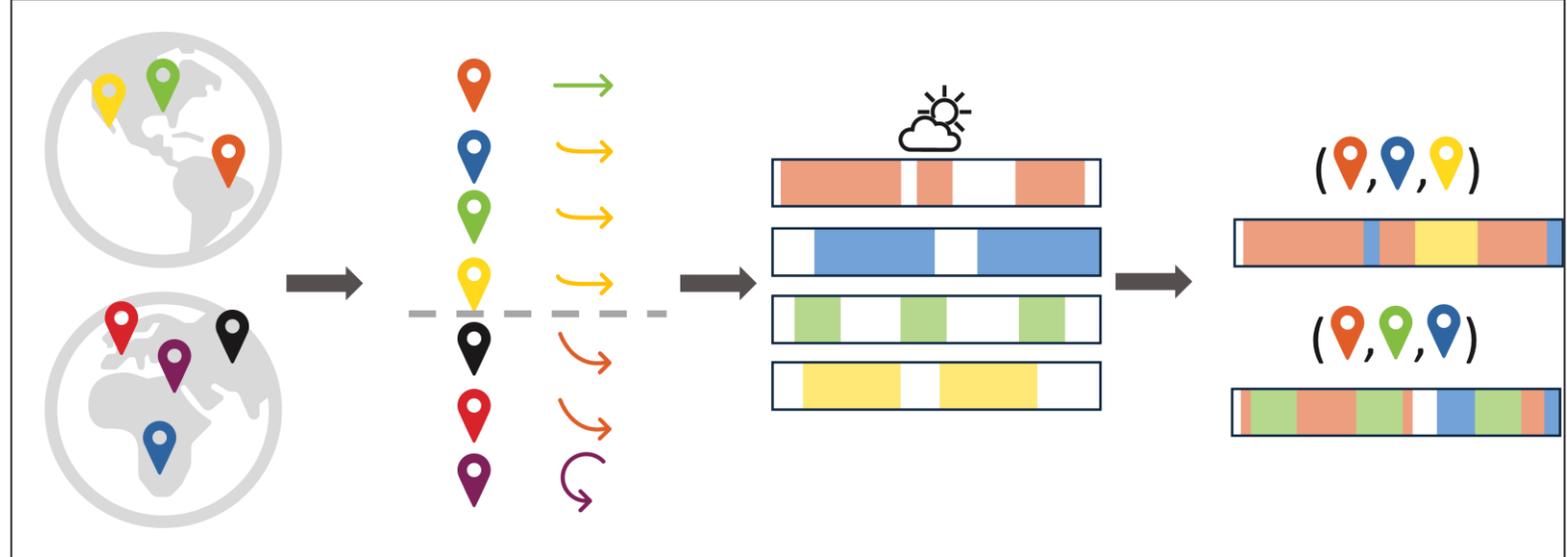


“100%” Site Network

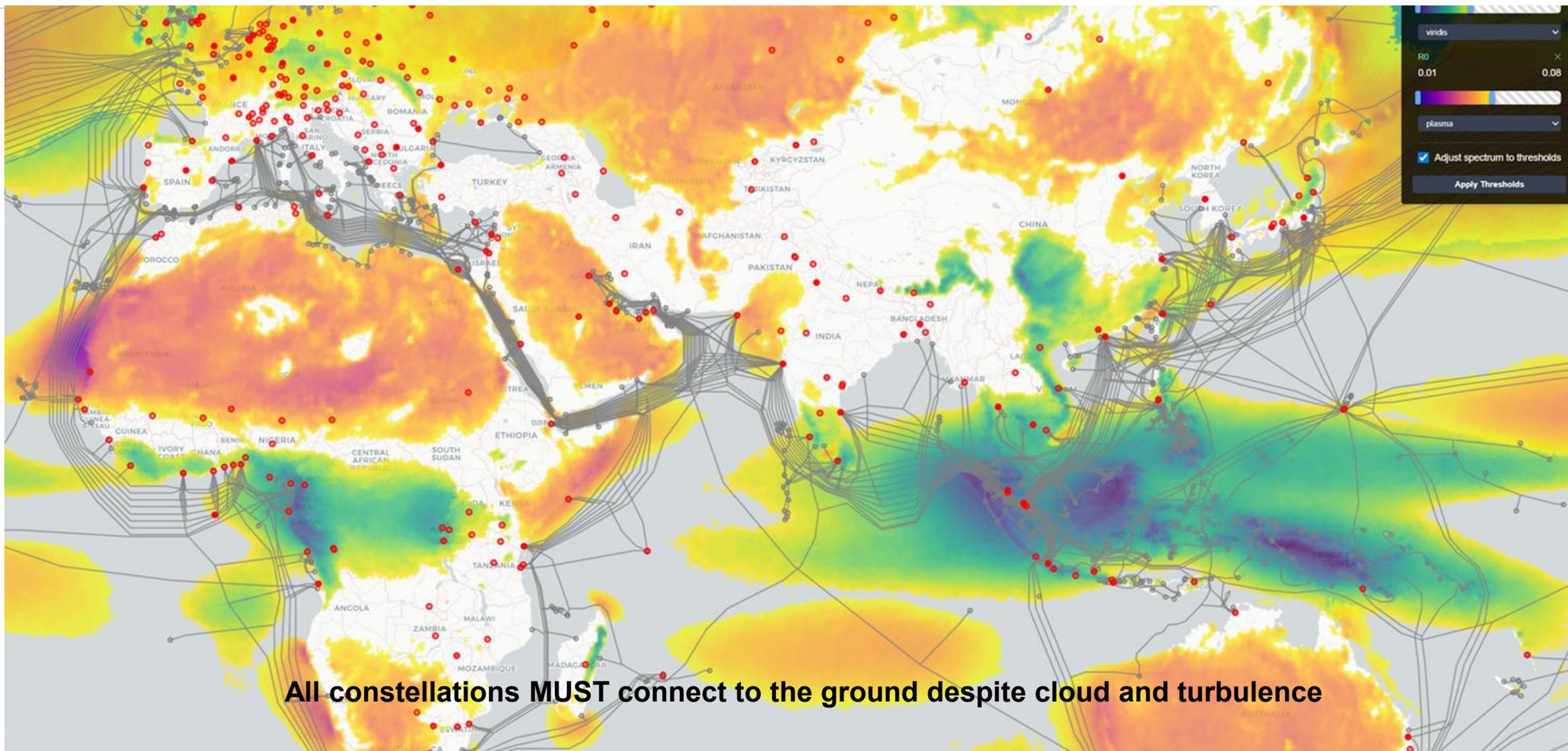
Cloud and turbulence thresholds
 Complementarity visualization

Statistical Visualization

- Histograms
- Yearly vs Daily distribution
- 3h temporal resolution
- 0.3 degrees spatial resolution
- 5 years of data (2021->2025)



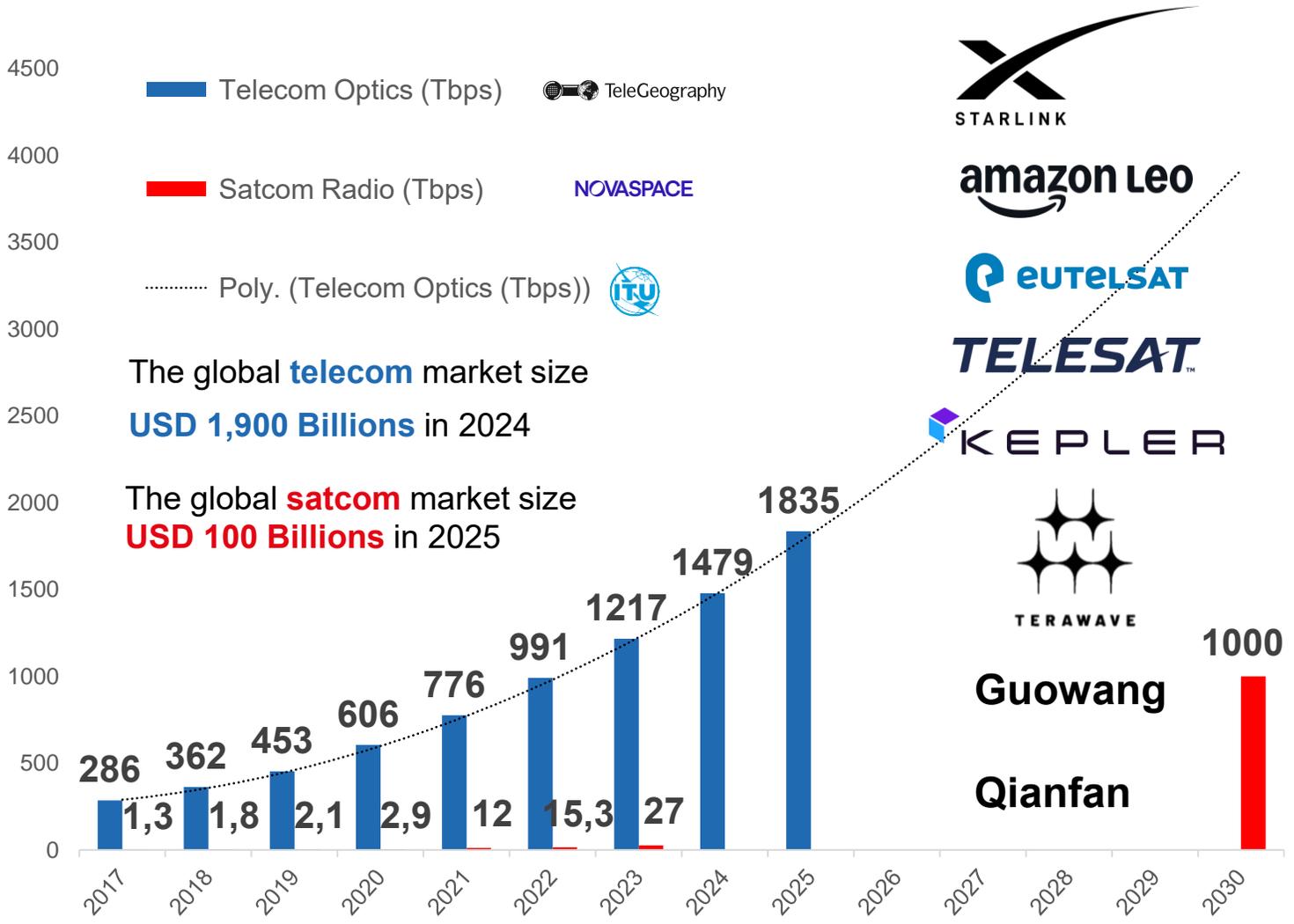
Key Asset: Terrestrial Telcom Global Infrastructure



All constellations MUST connect to the ground despite cloud and turbulence



Telecom and Satcom comparison



High Throughput Satellite vs Terrestrial fiber From 50 to 5 vs 0.5 \$/Mbps/month

Weighted average cost base of HTS capacity supply by region

