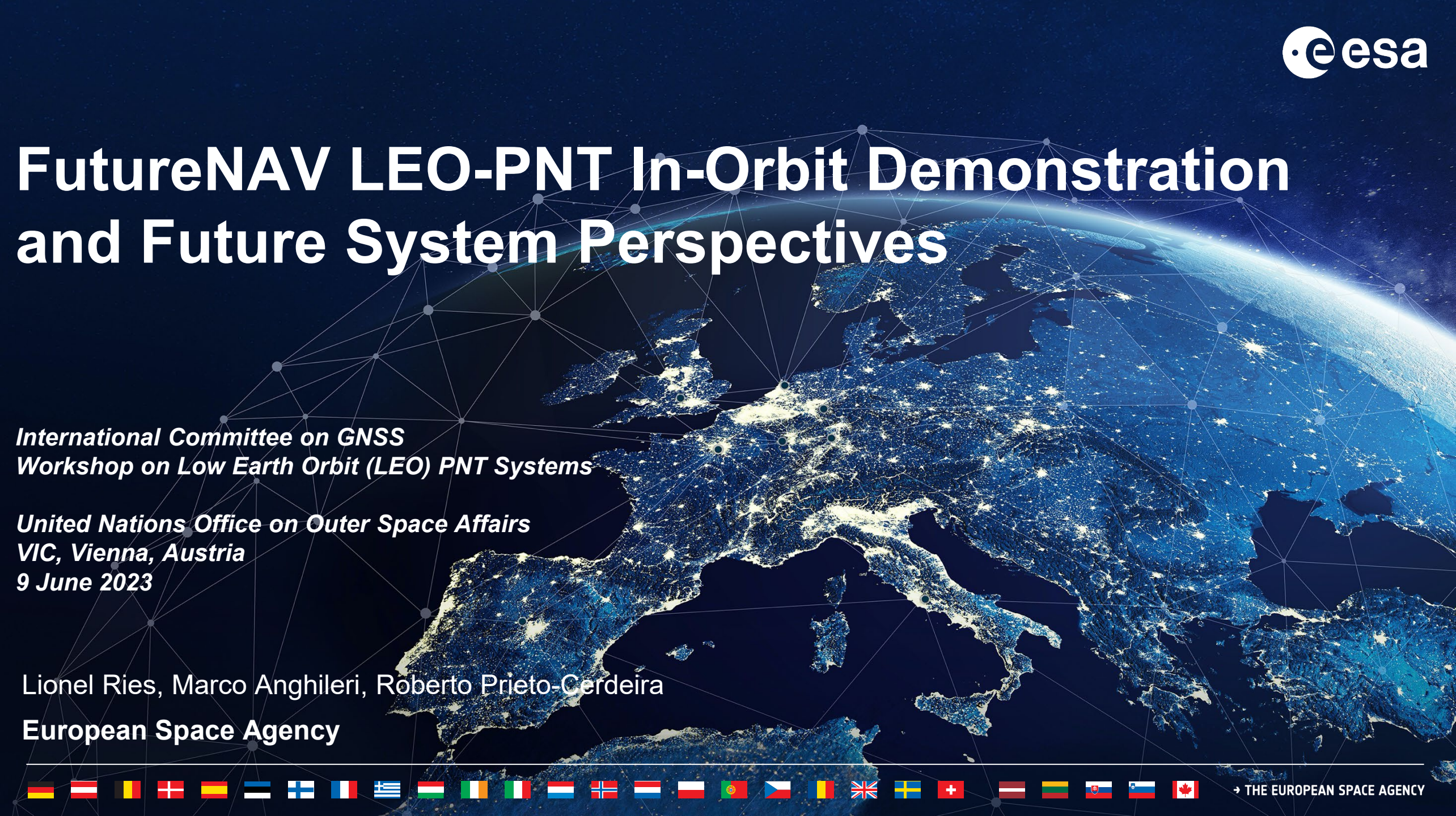
FutureNAV LEO-PNT In-Orbit Demonstration and Future System Perspectives



International Committee on GNSS
Workshop on Low Earth Orbit (LEO) PNT Systems

United Nations Office on Outer Space Affairs
VIC, Vienna, Austria
9 June 2023

Lionel Ries, Marco Anghileri, Roberto Prieto-Cerdeira

European Space Agency

LEO-PNT Context / Motivation

Evolution of SATNAV towards Multi-layer PNT

GNSS / PNT : 1st spin-off of space applications

- 6.5 billion receivers, 150 billion euros / year (Euroconsult/EUSPA), 10% annual market growth in next decade
- Essential component of global economy, smart mobility, etc.

GNSS huge success inspires more demanding needs

New models for LEO infrastructures

- New industrial models – large scale manufacturing and launches
- New business models - complementarity vs backbone systems, scalability
- New opportunities - distributed infrastructures, standardisation (e.g. 5G NTN)

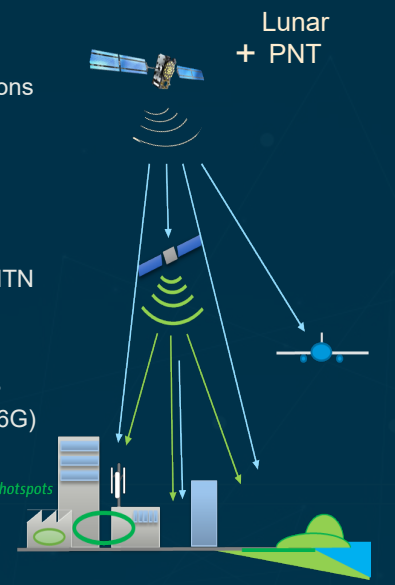
→ Evolution of SATNAV towards **Multi-Layer System-of-Systems**

Layer 1 – MEO/IGSO/GEO
- GNSS and their evolutions for global references / keystones

Layer 2 – LEO
- LEO-PNT, VDES, 5G NTN

Layer 3 – Local components
- PNT hotspots (e.g. 5G/6G)

Layer 4 – Dead-reckoning

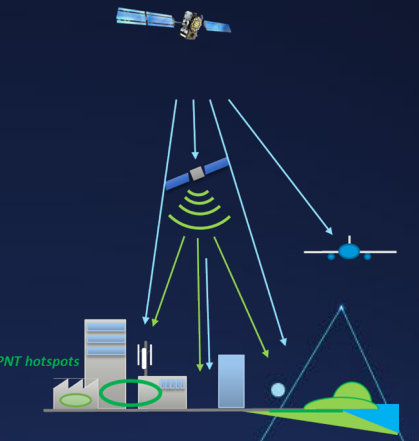


LEO-PNT fully complementary & boosting MEO GNSS backbone

Vision PNT-2030:
Ubiquitous, Reliable (Integrity), Resilient, dm-level and ns-level Accuracy

Enabled by a Multi-layer System-of-Systems PNT architecture

Multi-layer PNT architecture



Frequency Diversity

Connectivity & 2-way PNT

Sensor Fusion & Antenna Diversity for User Equipment

State-of-the-art of mass-market chipset

400 MHz bw,
4x4 MIMO
Multiple RF
(L, S, C, FR2)

5G

Potential exist to process the full GNSS L-band on 4 antennas ?

LEO-PNT: System Concepts and Differentiators

Purpose-built LEO-PNT

PNT measurements derived from PNT signals – dedicated SV or PNT hosted payload (e.g. on satcom)

- Signal / frequencies designed for PNT
- Geometry designed for PNT (dedicated) or for hosting systems

Fused PNT with Satcom

PNT measurements derived from satcom signals

- Signals / frequencies designed for satcom, with tailoring for PNT
- Constellation geometry and antenna coverage : constrained by hosting system

Signals of Opportunity (SOOP)

PNT measurements derived from 3rd party signals

- Signal / Frequencies designed for 3rd party missions
- Constellation geometry and antenna coverage: constrained by hosting system
- Ad-hoc monitoring necessary to support commitment of PNT service provider

LEO PNT differentiators - a combination of

LEO specificities, Frequency diversity, NAV / COM synergies

Lower free space losses

- Facilitator for compact payloads, frequency diversity and 2way PNT links

GNSS-enabled ODTS

- Complemented by ISL

Measurement Diversity

- Decorrelation, whitening of multipath, shorter outages, etc.

2-way PNT links

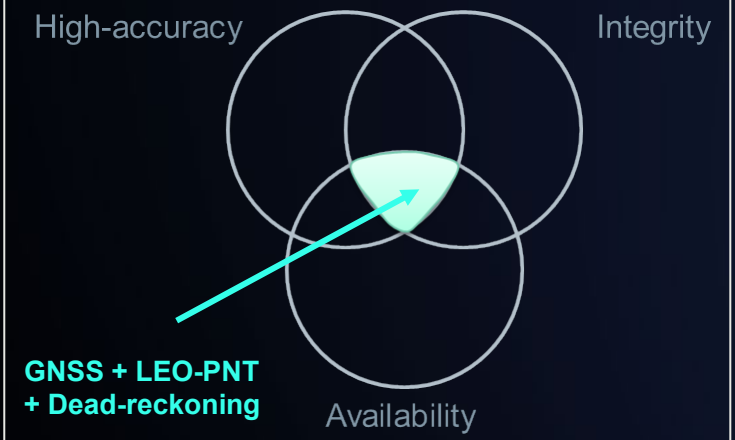
Frequency Diversity

5G Satcom - NTN
(Non-Terrestrial Networks)

LEO-PNT: Key Use Cases

Enhanced performance in challenging environments

(e.g. for autonomous systems)



Low energy positioning

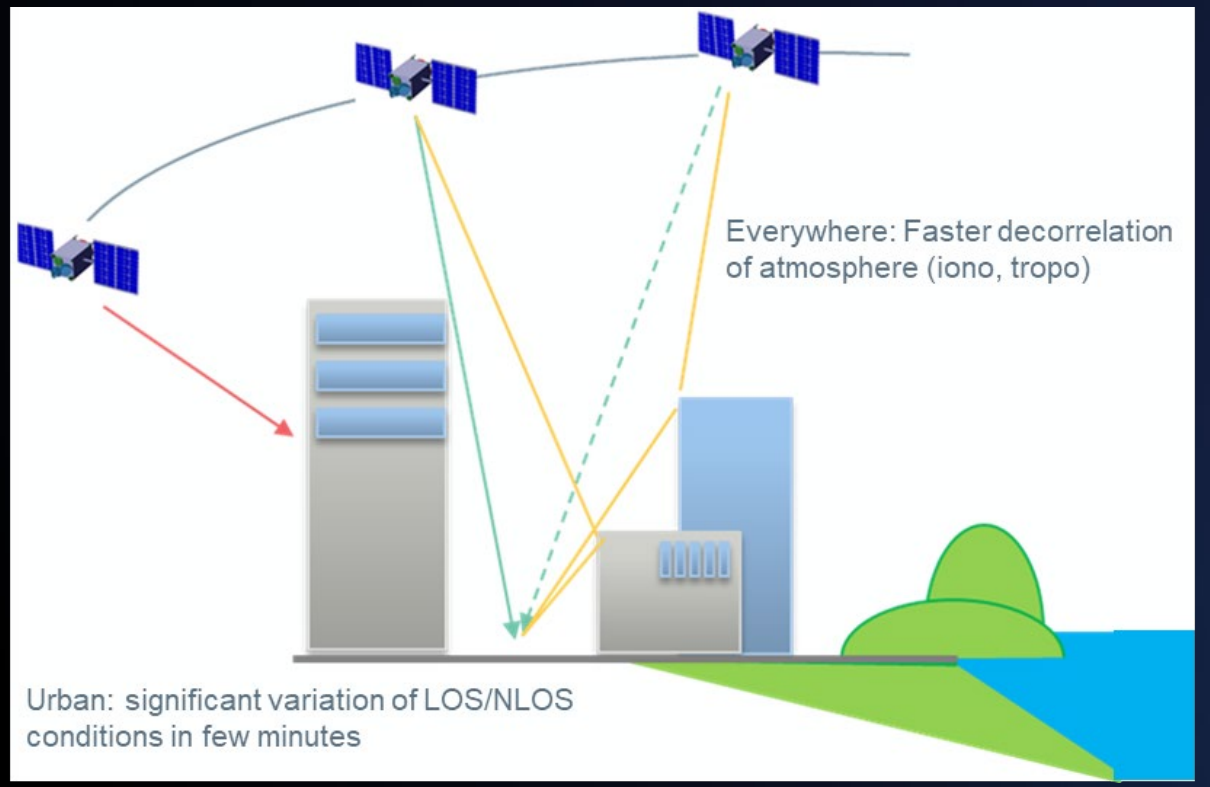
(e.g. asset tracking)

Enhanced robustness / resilience

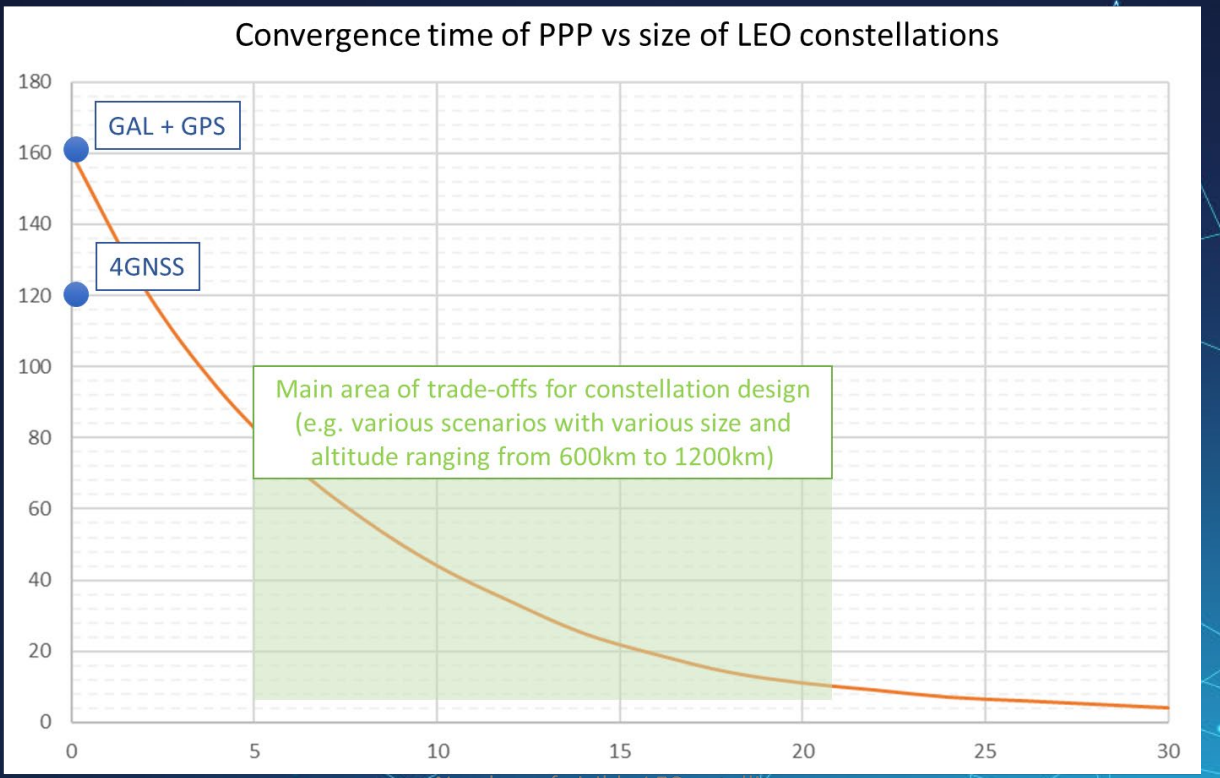
Measurement Diversity

Enhanced measurements diversity enabled by faster SV motion

- Measurement decorrelation: reduced convergence time for PPP algorithms (GNSS + LEO)
- Doppler-based positioning (1-3 satellites): improved availability, but lower accuracy (3m–100m)
- Shorter outages in case of NLOS: improved coasting with drifting sensors (e.g. IMU, MAC or equivalent)



Example: Faster convergence of PPP algorithms

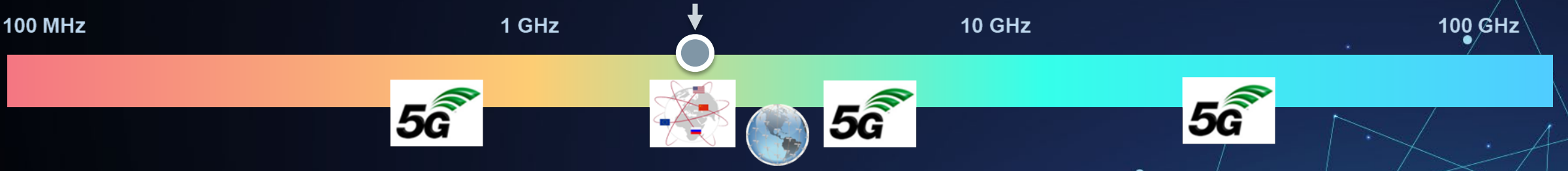


The Opportunities of Frequency Diversity

Low Size-Weight-Power payload and low Time-To-Market facilitates the introduction of additional frequencies for improved frequency diversity

L/S bands : "sweet point"
for small form factor Rx
(GNSS, MSS, etc.)

100 MHz | 1 GHz | 10 GHz | 100 GHz



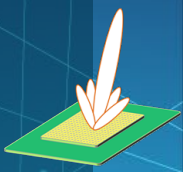
Lower frequencies
(< 1 GHz)

- ☺ Improved penetration (canopy, indoor)
- ☺ Larger wavelength (carrier ambiguity)
- ☺ Improved iono-free combination when combined to L or S
- 😐 ITU allocations

Opportunity to extend frequency diversity of SATNAV outside L/S band for new physical properties of RF link

Higher frequencies
(> 4 GHz, up to Ka-band)

- ☺ Accuracy / Reliability
- ☺ High directivity of user antenna
- ☺ Opportunity for PNT-satcom synergies
- 😐 Form factor of UE antenna



The Opportunities of 5G NTN for LEO-PNT

5G NTN – Non-Terrestrial Network – is the satellite component of 5G

	2020	2021	2022	2023	2024	2025
3GPP	Release 17		Release 18		Release 19 and beyond	
Backhaul	System features to **support backhaul over legacy satellite transport** network - static latency and bandwidth		System features to support backhaul over legacy satellite transport network - variable latency and bandwidth		*Possible next steps* • *Regenerative payloads* • *Broadcasting* • *V2X* • *Etc*	
Access	5G NR & 4G NB-IoT/eMTC features to **support satellite access with transparent payload**		Enhancements to support transparent satellite access			
	Radio-part : specifications for **FR1 – L/S bands**		Radio-part : specifications for **FR2 - > 10 GHz**			
Positioning	**GNSS-based**, in support of NTN signaling (cell management, doppler compensation, etc.)		GNSS Network-verified UE location		TBC: Additional enablers for NTN positioning (RAT-dependent)	

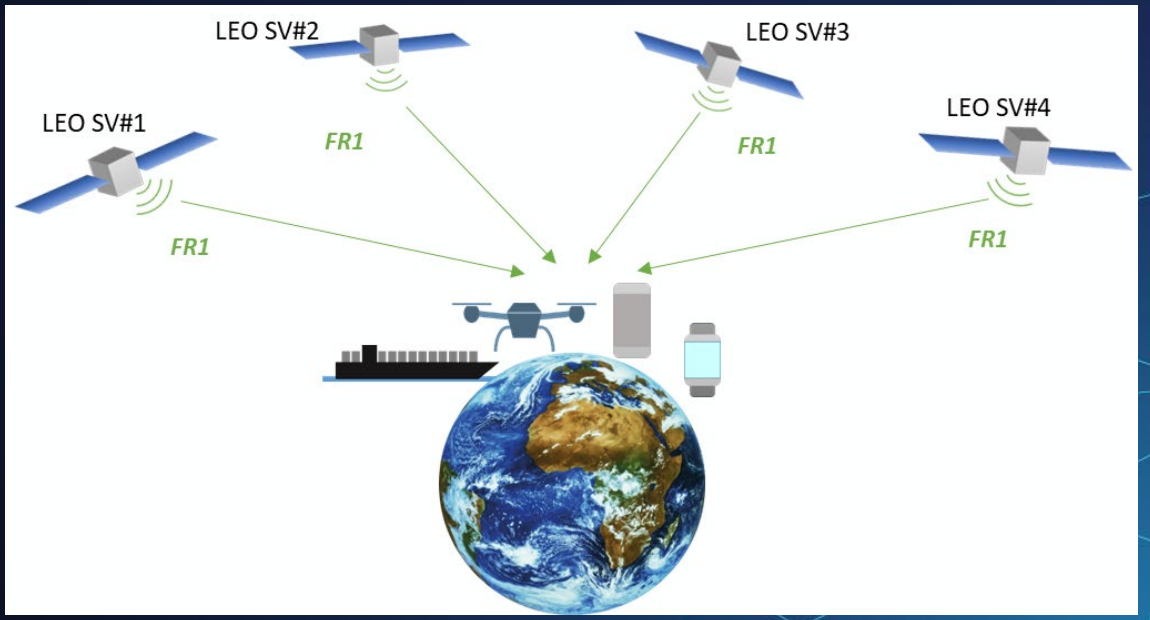
Potential change of paradigm for 5G Positioning technologies, bringing coverage **from local to global**

Positioning with 5G NTN

Particularly interesting for mobile and new classes of users addressed by 3GPP

- Exploitation of Com / NAV synergies
- Devised from 3GPP SA1 “Study on Satellite Access – Phase 3”, where access of devices without GNSS is being considered
- Target various use cases and waveforms, including for low-complexity processing

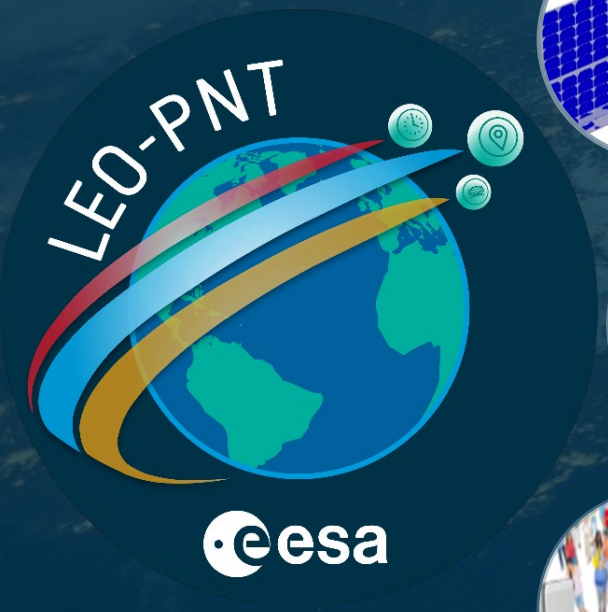
Illustrative concept: Implementation of NTN ranging signals over satellites using 3GPP radio air interface (waveform and frequency), featuring PNT-friendly geometry (e.g., GNSS-like)

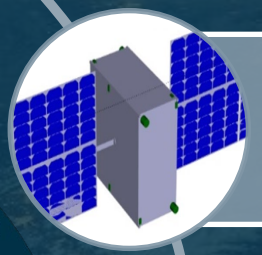


The FutureNAV LEO-PNT Programme

ESA's FutureNAV LEO-PNT Objectives

Accelerate LEO-PNT from concepts to demonstration through **Fast-Track In-Orbit Demonstration**, and **prepare added-value services for potential future LEO-PNT systems**.

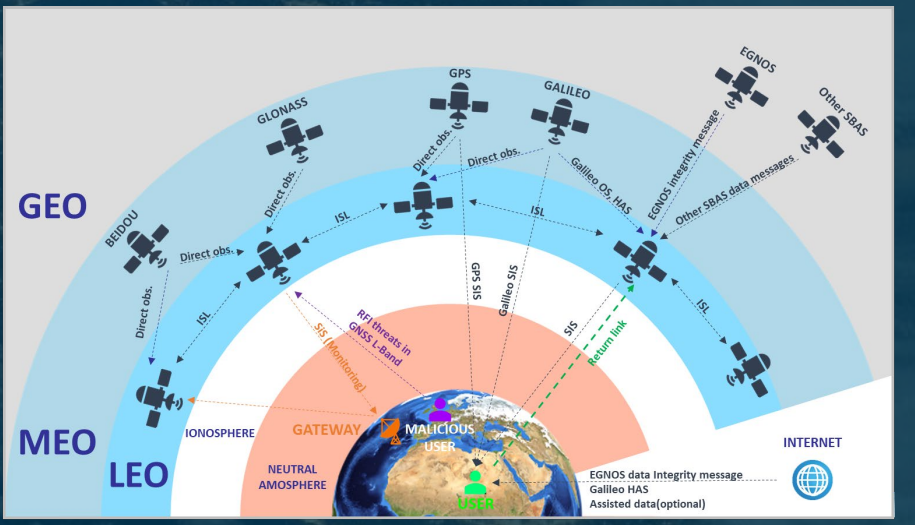




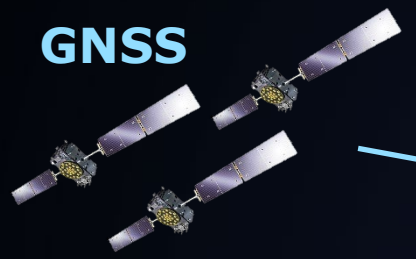
Develop enabling technologies

Demonstrate services

De-risk adoption – standards, regulatory, …



ESA's FutureNAV LEO-PNT IoD – System Overview



GNSS

LEO-PNT IOD Satellites

GNSS SIS

Frequency diversity, L/S + others

LEO-PNT SIS

2-way PNT

Test User Segment

Lean Ground Segment

Future LEO-PNT System Perspectives

Future LEO-PNT System Perspectives in Europe

LEO-PNT Preparatory studies

FutureNAV LEO-PNT In-Orbit Demonstration

COMMERCIAL Operational Programmes

INSTITUTIONAL Operational Programmes

In-orbit Service Demonstration
Develop Enabling Technologies

COMMERCIAL prospects
European Industries aiming commercial services based on LEO-PNT

INSTITUTIONAL prospects
e.g. EU IRIS², Galileo

Possible Areas of Coordination

Possible Areas of Coordination

The following aspects may be subject of coordination among current and future LEO-PNT systems:

- **Spectrum aspects** (frequency coordination, protection of spectrum, usage of new bands for radionavigation)
- **Space debris mitigation**
- **Compatibility / interoperability** among LEO-PNT systems and with GNSS/SBAS
- **Use of standards**

Summary

Summary

- **Opportunities** are identified for **PNT from LEO orbit to complement / augment existing GNSS systems** in response to current, future, diverse and challenging user needs

  ➔ LEO-PNT has the potential to be a major contributor to GNSS and PNT in general

- **ESA's FutureNAV LEO-PNT In-Orbit Demonstration** established to demonstrate services and enabling technologies in preparation of future operational systems
- **In Europe**, given GNSS industrial competences, Commercial and/or Institutional prospective, **LEO-PNT systems could be envisaged in the future**
- A number of areas have been identified for possible follow-up **coordination** including **spectrum, space debris, compatibility and interoperability, and usage of standards**


Thank you for your attention
Any Questions?