



ESA's LEO-PNT In-Orbit Demonstration Mission and the Future

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IEEE LEO Sats Workshop
"LEO Position, Navigating, and Timing (PNT)"
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SatNav: A strategic sector, also in Europe



10% of EU's GDP relies on SatNav systems and its set to grow.

But not without challenges and risks.

Satellite navigation is the largest downstream space market



4+ billion Galileo users worldwide / EGNOS fully integrated in aviation



Strategic enabler for European autonomy and resilience (Dual Use)





50.000 jobs in European GNSS downstream market



Europe as a strong international partner



GNSS Interference Incidents, 30-March to 01-April 2025 Source: GPSWise, https://spoofing.skai-data-services.com/

Evolution of SatNav towards Multi-Layer Positioning, Navigation and Timing (PNT)



Multi-Layer PNT with LEO-PNT fully complementary & boosting MEO GNSS backbone:

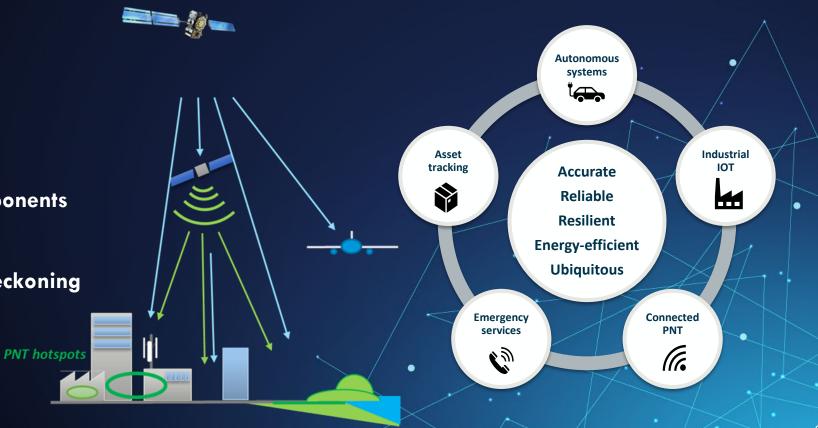
Layer 1 – GNSS at MEO/IGSO/GEO global references - anchors

Layer 2 – LEO-PNT

PNT diversity nodes in space

Layer 3 – Local/regional terrestrial components e.g. 5G PNT, WLAN

Layer 4 – Sensors, Inertial units, Dead-reckoning at User Equipment level



LEO-PNT International Initiatives



Several initiatives worldwide for LEO-PNT:

Europe, China, US, Japan, UAE, Russia, S. Korea, Turkey

United Nations International Committee on GNSS (UN-ICG):

- LEO-PNT continues to be a worldwide trend being one of the emerging topics of most interest by international providers.
- A regular annual LEO-PNT workshop has been established with the objective to discuss and develop a reference standard for LEO-PNT interoperability and compatibility.
- Commercial opportunities arising worldwide.













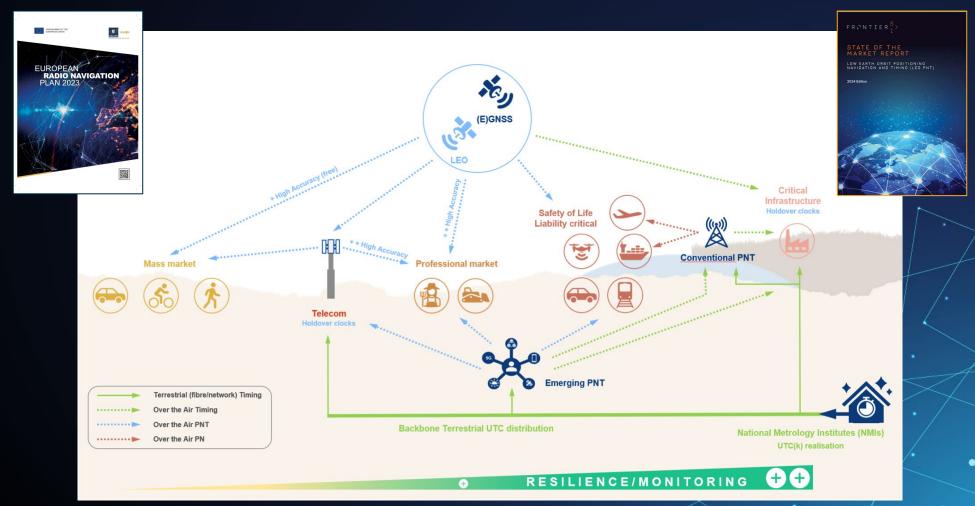
Xona PULSAR

* A new North Star to guide the age of Autonomy

Multi-Layer System of Systems



Future GNSS will be multi-layer with IGSO, LEO, MEO and GEO constellations (layers)



Summary of LEO-PNT Benefits and Differentiators

esa



Resilience (more bands, wider bands, user equipment and antenna, etc.)

Backup / Alternative PNT

Performance (low ionosphere in C-band, etc.)

Frequency Diversity

Distance to user • On-board ODTS •

- Lower Free Space Loss
 - Less demanding PL
- Less demanding GSEG
- 2-way links more feasible

Performance (PPP convergence time, multipath mitigation)

Increased availability in challenging environments e.g. canyons, high latitude

Redundancy

Geometry
Dynamics
Coverage

Possibilities for new services

Positioning for emergency situations

eCall

Situational Awareness

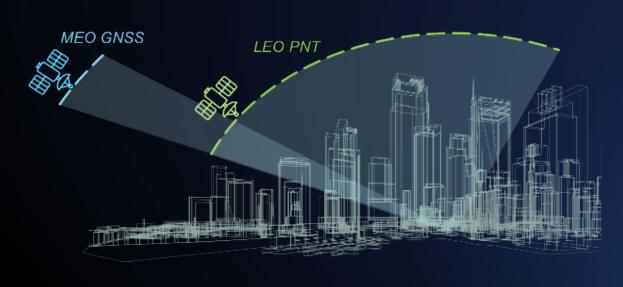
Indoor

Measurement Diversity



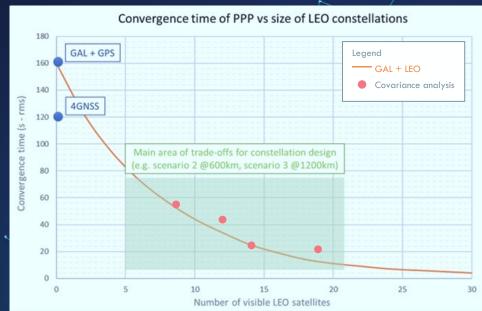
Enhanced measurements diversity enabled by faster SV motion:

- Measurement decorrelation, faster with respect to MEO: reduced convergence time for PPP algorithms (GNSS + LEO)
- Urban: significant variations of LoS / NLoS conditions in few minutes
- 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)



Simulations results for PPP convergence time

Theoretical trends, covariance analysis, augmented reality (real MEO measurements)

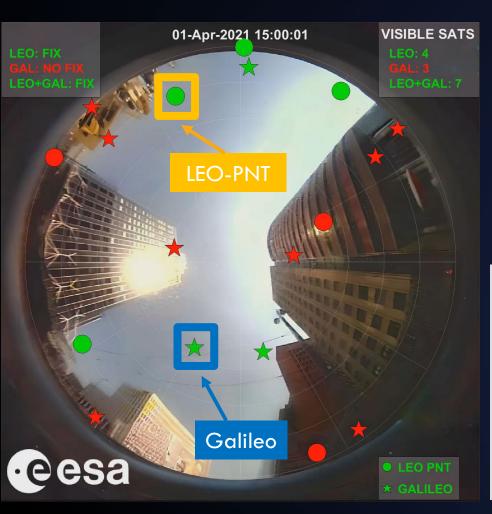


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Example: Measurement Diversity in Urban Scenario

with LEO + GAL





Urban scenario with Galileo and LEO-PNT

LEO constellation of 60 SV in polar orbits

Valid Fix is considered if GDOP < 10



after > 15 min

Frequency Diversity - Opportunities for New Bands





PPP (carrier) provides high accuracy but still faces some shortcomings: convergence time and robustness

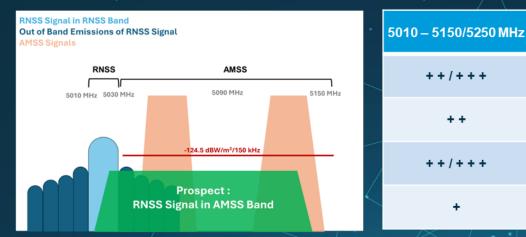
K-band and up



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Frequency band (MHz)	460-470	1164 – 1215	2483 - 2500	5010 - 5030	
Bandwidth	=	++	=	=	+++
lonosphere		=	=	++	+++
UE form factor	-	++	++	++/+++	
Techno. maturity (PNT)		+++	+++	+	
Penetration	++	=	=	-	

Opportunity of extending RNSS C-band to 5010 - 5150 MHz or 5010 - 5250 MHz?

(up to 140 or 240 MHz bandwidth)



Transmission below the existing PFD limits provides enough power to be shared among future RNSS providers

Proposed Action Item for ITU WRC-31 to extend primary RNSS allocation in [5030 - 5250] MHz - typically within existing PFD limits

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ESA's LEO-PNT — Main Strategic Pillars



Pillar I

Resilience and Robustness

RESILIENT AND ROBUST PNT

User level vs Jamming and
Spoofing
Different types of users (critical

infrastructure, professional,
mass-market, ...)

New frequency bands (C, S, FusedPNT, ...)



Pillar II

Galileo/EGNOS Augmentation

ADDED PERFORMANCE

PPP Fast Convergence
Urban Performance
NAV Data dissemination

GALILEO/EGNOS +

GSS in space
Integrity monitoring
Connectivity with MEO via (O)ISL



Pillar III

New Service Capabilities

S-BD 2-WAY 6G NTN PNT

PNT for Personal Emergency and
Public Safety
Low Energy PNT for IoT

UHF/VHF PNT

Indoor timing and/or positioning
Positioning under heavy shadowed
areas



ESA's LEO-PNT In-Orbit Demonstrator (IOD)





Demonstrate LEO-PNT concept and services



Mature and de-risk key enabling technologies



De-risk adoption - standards, regulatory, ...



IOD **Experiments**



Accelerate LEO-PNT from concept to demonstration through a fast-track in-orbit demonstration and prepare added-value services for potential future operational LEO-PNT systems.



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LEO-PNT IOD — Industrial Contracts



2 parallel contracts

mini-constellation deployment: 2025 - 2027

Each including:

System and Space segment

Launch services

Ground segment & operations

Test User segment

Experimentation and Service demonstration

1 Pathfinder A satellite:

Launch ready by end 2025

Quasi-polar orbit at ~550 km

PNT signals in L and S bands

De-risking and 1-SV experiments

12-month lifetime

4 Pathfinder B satellites:

Launch ready by end 2026

Quasi-polar orbits at ~550 km

PNT signals in L, S, UHF, C bands + 2 way

Service demonstration (4-SV experiments)

16-month lifetime



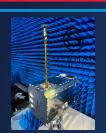
Platform by Alén Space 12U Cubesat



Platform by OHB <100 kg microsat



Platform by GOS 16U Cubesat-like



Platform by Deimos <100 kg microsat



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ThalesAlenia

LEO-PNT IOD — Pathfinder A



GMV

Technical specs (platform)

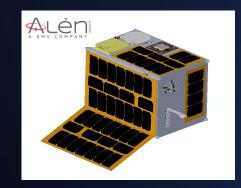
- 12U form factor
- Approx. 20kg
- Fixed deployable and body mounted solar panels
- S-band for TMTC and Feeder link
- Dedicated GNSS to platform
- Chemical propulsion
- 3-axis stabilized ADCS w/o star tracker

Technical specs (payload)

- On-board ODTS
- CMCS
- SGU
- L-band patch, S-band patch

<u>Launch</u>

Q4 2025 (Vega-C or Transporter)



TASF

Technical specs (platform)

- 16U form factor
- Approx. 30kg
- Fixed deployable and body mounted solar panels
- S-band for TMTC and PL data
- Dedicated GNSS to platform
- FEEP propulsion
- 3-axis stabilized ADCS with star tracker

Technical specs (payload)

- On-board ODTS
- CMCS
- SGU
- L-band QHA and \$-band patch

Launch

Q4 2025 (Vega-C or Transporter)



LEO-PNT IOD — Pathfinder B



GMV

- System Validation and Service Demonstration
 - L S UHF C bands
 - 2 two-way services
 - additional payloads
- 4 Small satellites (mass < 100kg)
- 2 satellites per plane on nearby orbital planes
- 36 months lifetime



TASF

- System Validation and Service Demonstration
 - L S UHF C bands
 - 2 two-way services
 - additional payloads
- 4 Small satellites (mass < 100kg)
- 2 satellites per plane on nearby orbital planes
- 36 months lifetime







TAS- Italy – SSeg Prime

Deimos – Platform

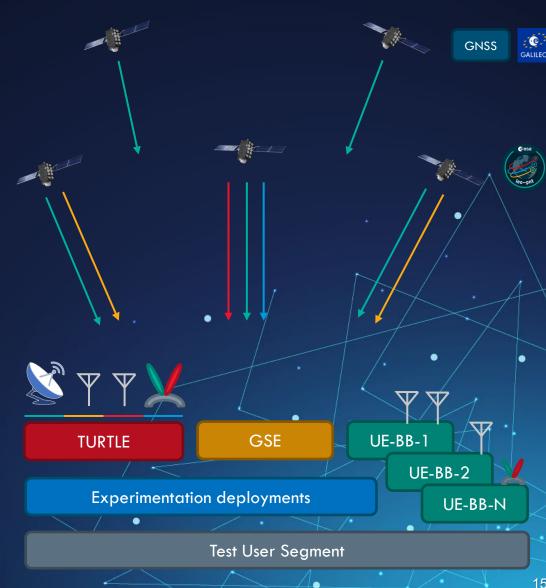
Launch readiness before end of 2026

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LEO-PNT IOD — Ground and User Segments



- Lean Ground Segment for ground monitoring and control:
 - Ground Segment provides all M&C of the LEO-PNT satellites and operates the mission payload during LEOP, routine phase, and special operations
 - Ground Segment responsible for reception of mission data from the satellites as well as provision of the products required for the IOD campaign
- Test User Segment for experimentation and demonstration:
 - Several realizations of user types (UE-BB) as well as a reference Test User Receiver and Transmitter for LEO-PNT (TURTLE)
 - Ground Support Equipment (GSE) and interfaces with Ground Segment and Experimentation deployments
 - User equipment is deployed in support of experimentation both in-lab as in-field and targeting multiple user environments
 - Performs all IOD Signal-in-Space acquisition, tracking, PVT, signal quality monitoring, 2-way, PPP, recording, and logging.



LEO-PNT IOD — Experimentation





Experiments with 1 SV in View





ODTS accuracy



Ranging accuracy



Demonstration of payload



Validation of NAV signal generation, transmission, and signal reception



Experiments with 4 SV in View

PVT performance





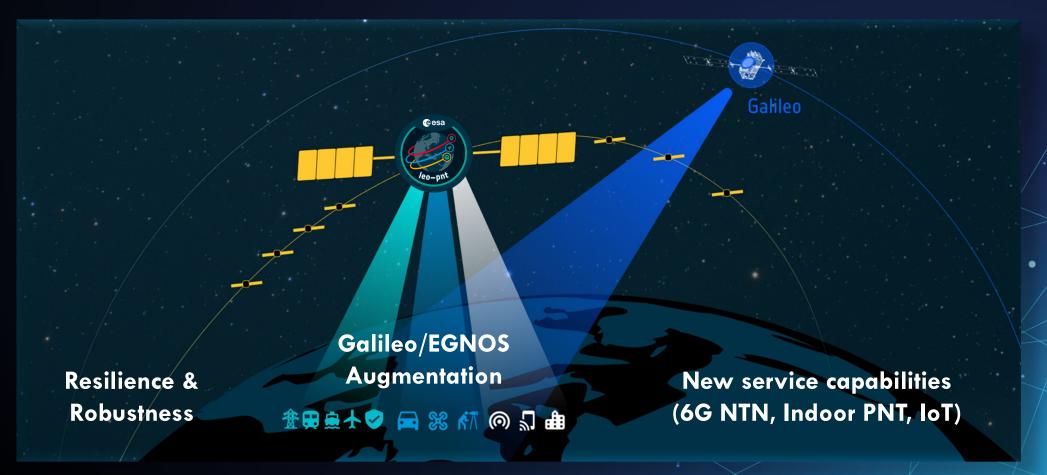
Experimental Service Demonstration

Next Steps: In-Orbit Preparatory Phase



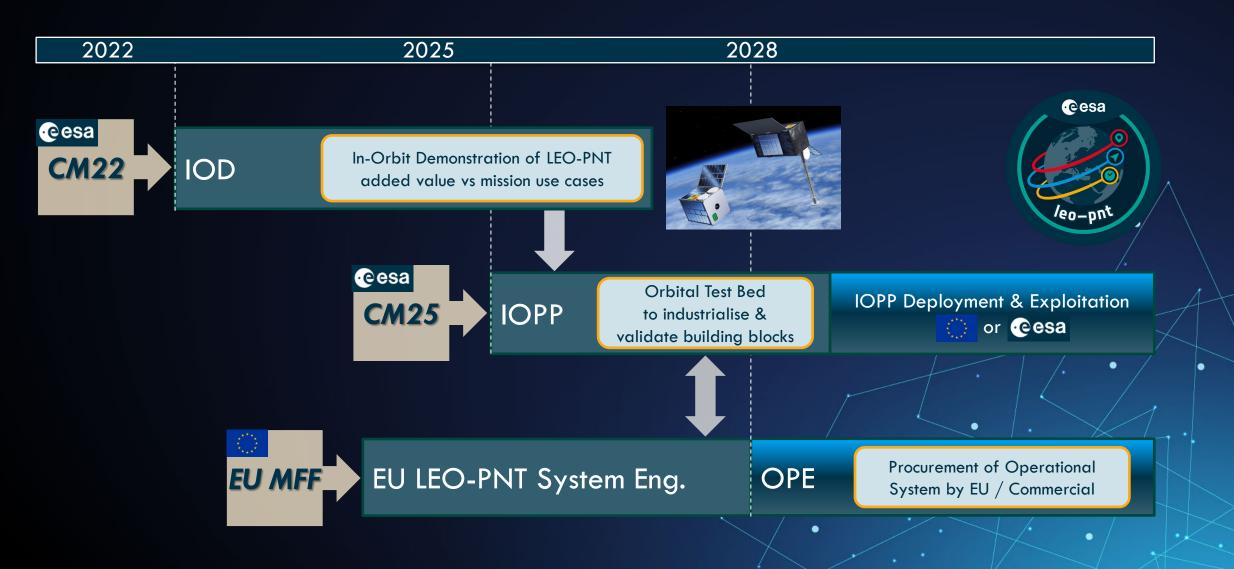
From Prototyping and Demonstration to Industrialisation and In-Orbit Validation...

...towards an EU Institutional operational system and supporting Commercial initiatives.



LEO-PNT In-Orbit Preparatory Phase (IOPP)





LEO-PNT Industrialization

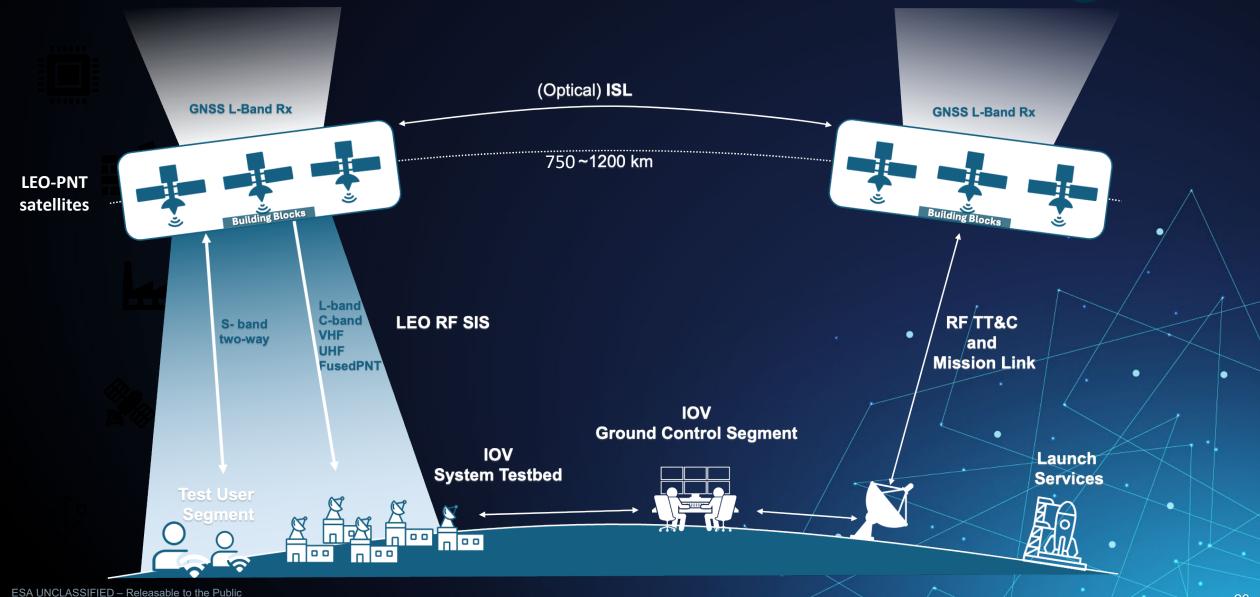


- Building blocks to be designed with product orientation in mind.
- Support the development and demonstration of building blocks' manufacturing and testing lines, including, when possible, automation and innovative processes and techniques.
- Demonstration of process-based qualification and acceptance through the verification of successful and reliable manufacturing of a representative number of products (i.e. building blocks) e.g. miniaturized payload modules, front-ends, antennas, clocks, ODTS, ISL, Rx chips.
- For satellite platforms and sub-systems, the programme will leverage existing European and national initiatives and smart factory developments currently ongoing in Europe.
- RFI on LEO-PNT industrialisation (Space Segment) launched in Q1 2025.

LEO-PNT next phase - Industrialisation and In-Orbit
Validation - Space Segment

LEO-PNT IOPP System Architecture





→ THE EUROPEAN SPACE AGENCY

Conclusions and Next Steps



- A LEO layer for Positioning, Navigation and Timing is a promising opportunity to improve GNSS resilience and robustness, improve GNSS performance and provide new services.
- Through the FutureNAV programme, ESA continues to foster the European LEO-PNT ecosystem.
- The ESA LEO-PNT In-Orbit Demonstration with 2 parallel contracts is underway at fast pace, to pave the way for a European GNSS LEO layer:
 - 10 In-Orbit Demonstrator satellites will be launched within the next 3 years.
- Possible opportunities for future operational system are under investigation from both Institutional (in coordination with EU) and Commercial perspectives.
- The LEO-PNT IOPP including Industrialisation and In-Orbit Validation is in motion for the next steps.

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Thank you for your attention!



