FutureNAV: Demonstrating the Future of Satellite Navigation

Industry Space Days 2024

INDUSTRY SPACE DAYS 2024 SPACE FOR BUSINESS OPPORTUNITIES

NAV Directorate

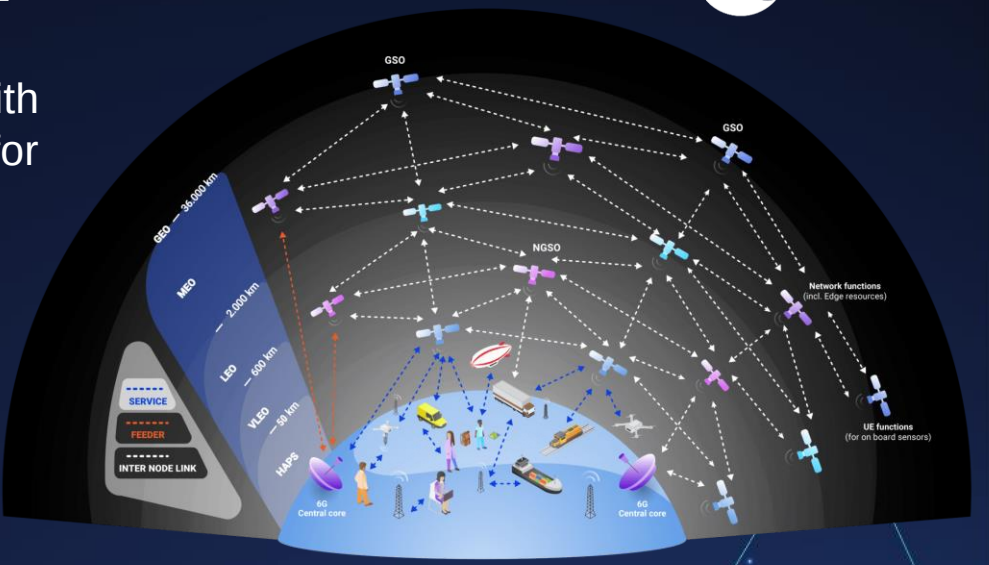
R. Prieto Cerdeira, D. Ibanez

roberto.prieto.cerdeira@esa.int, david.ibanez@esa.int

Major Trends in the GNSS / PNT Field

Resilience and Robustness: Multilayer system-of-systems architectures with IGSO, LEO and GEO constellations. Integrating 5G / 6G telecom networks for ubiquitous PNT.

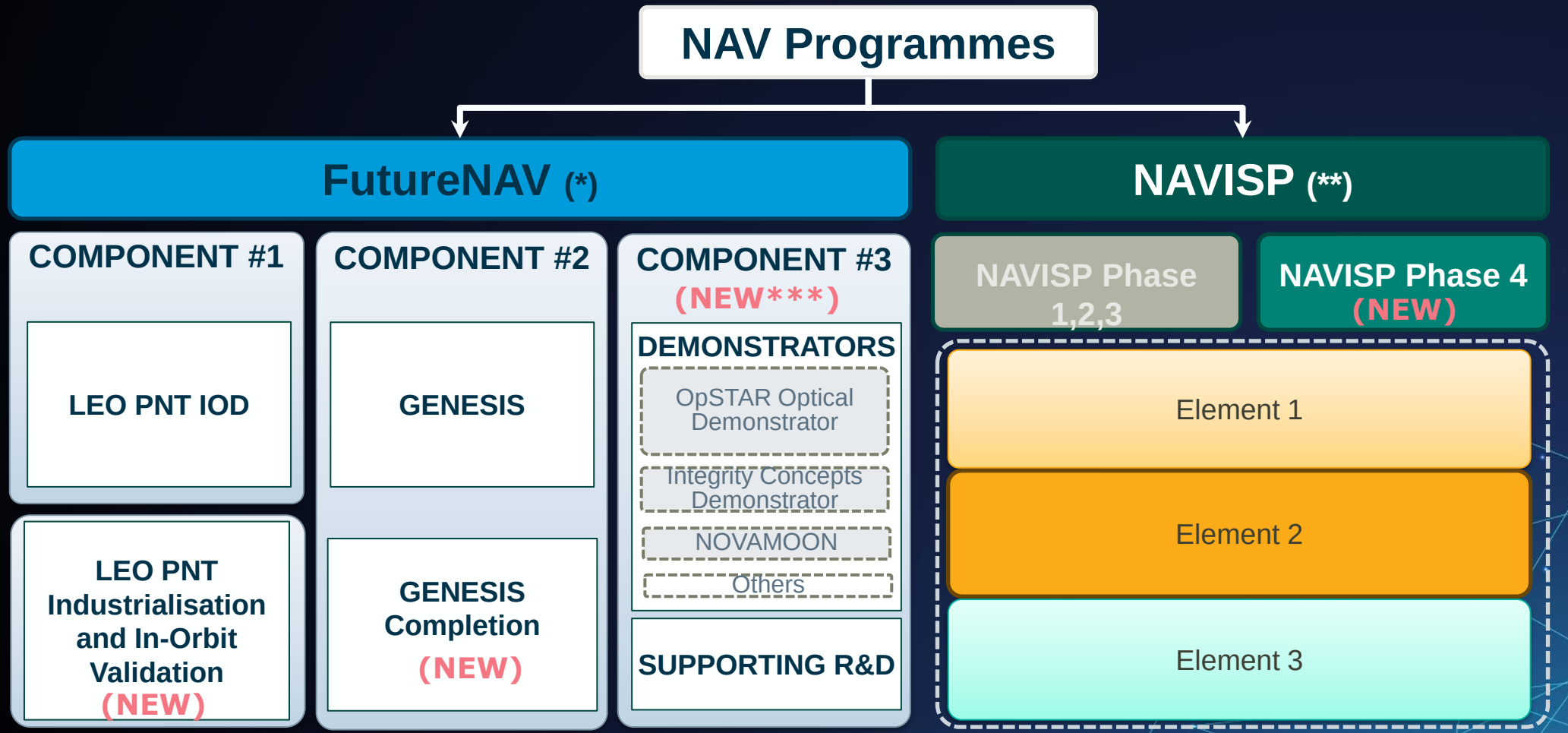
New Business Models: New space approach derived from megaconstellations aiming at low-cost, series production, fast time-to-market and use of COTS equipment.



Disruptive Technologies: Technological advances in disruptive technologies like Optical / Quantum Sensors, Signals of Opportunity, Artificial Intelligence / Machine Learning with major impacts on the design, provision, and usage of GNSS and PNT services.

Sustainable Development: GNSS providers will need to prioritize sustainability in their strategies, including the use of green technologies, as the environmental impact of satellite launches and operations comes under scrutiny.

NAV Programmatic Structure for CM25



(*) The final programmatic approach for LEO PNT Next is still under definition (extension of Component #1 vs a dedicated Component).

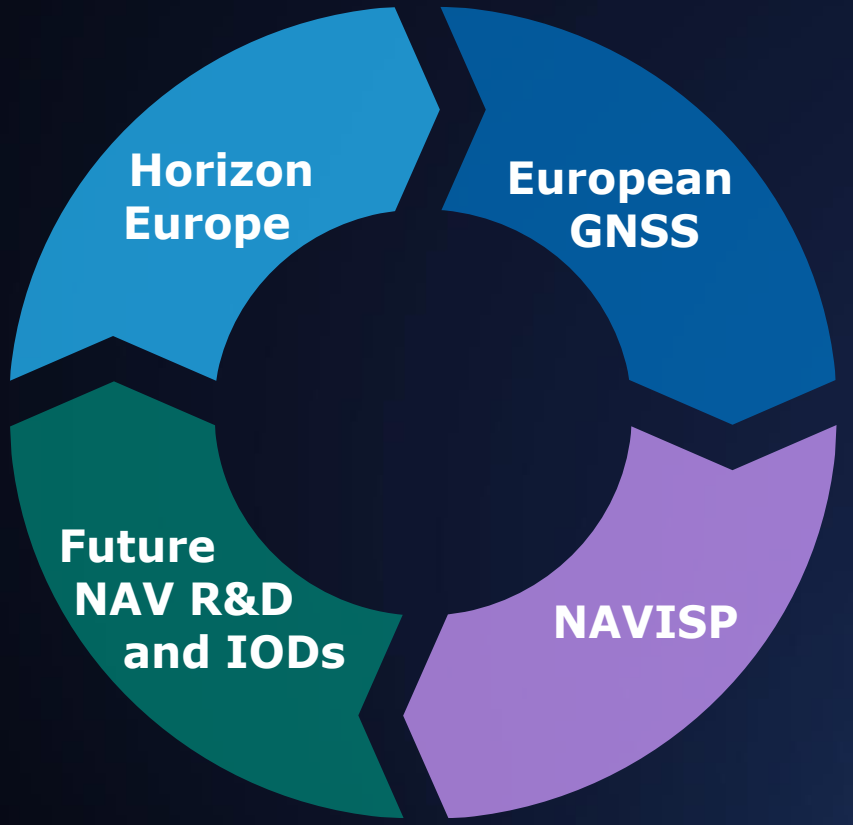
(**) Reflections are on-going on the reduction of the number of budget lines associated to the NAVISP Programme.

(***) Component 3 programme proposal and Implementing Rules under definition at PBNAV level.

Principles of Synergy & Complementarity with EU-Funded Activities

EU-funded activities focusing on operational infrastructure and its evolutions

Tailoring to EU Programmes and preparation of EGNSS



Operational Service Provision

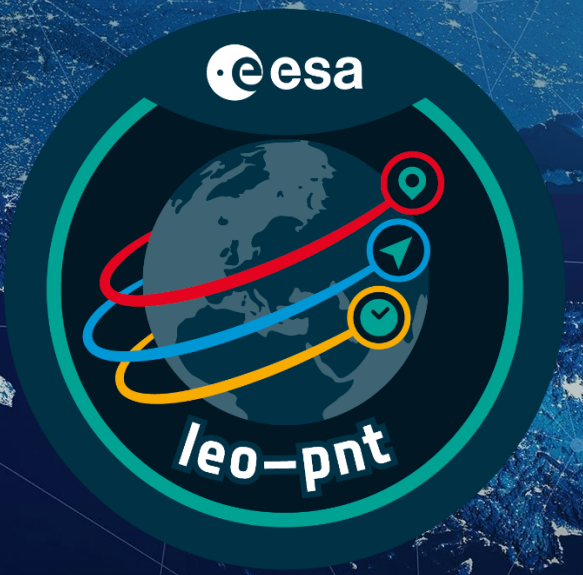
Anticipating & validating Future PNT Technologies

Leveraging downstream market for Future PNT needs

EC-ESA coordination process aiming at complementarity of MFF and ESA NAV portfolio.

ESA NAV Programmes addressing future PNT needs, and European Industry's readiness

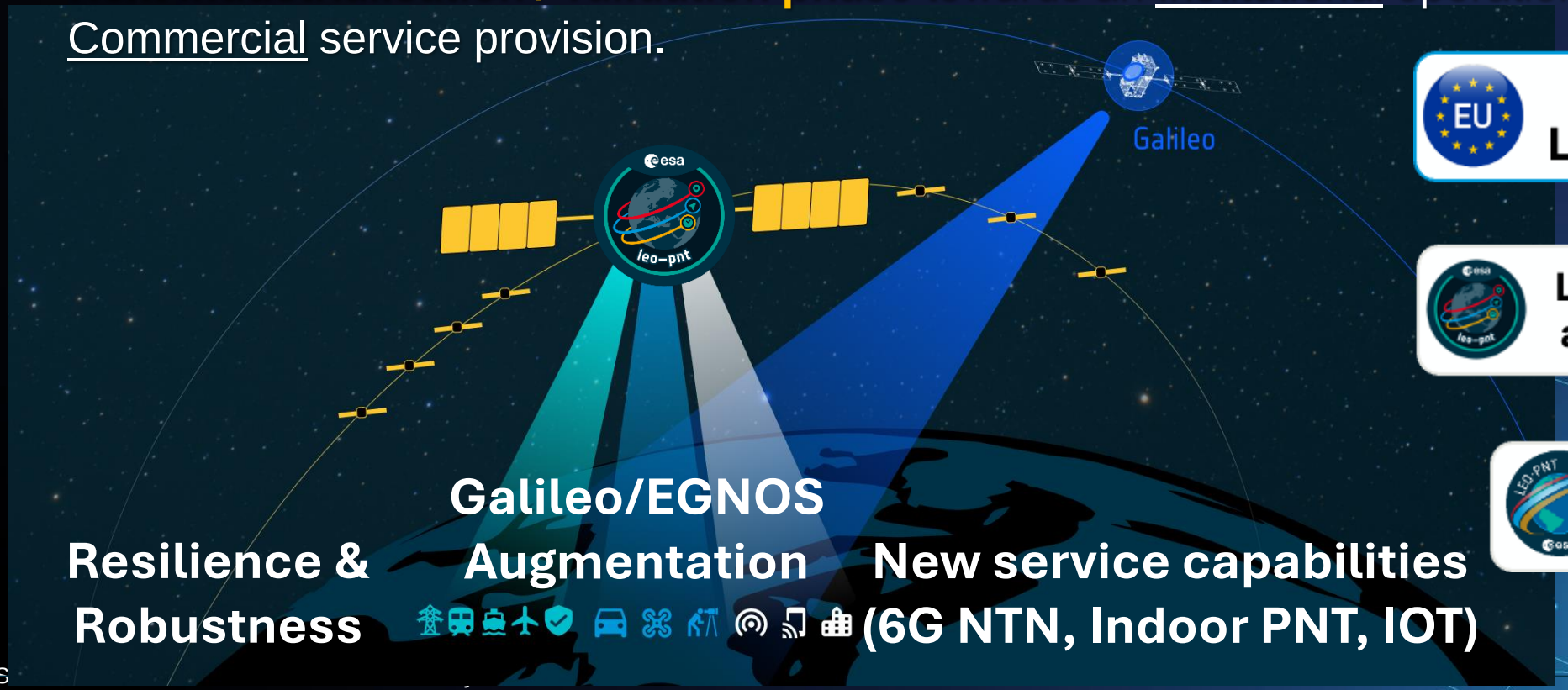
LEO-PNT Industrialisation and In-Orbit Validation

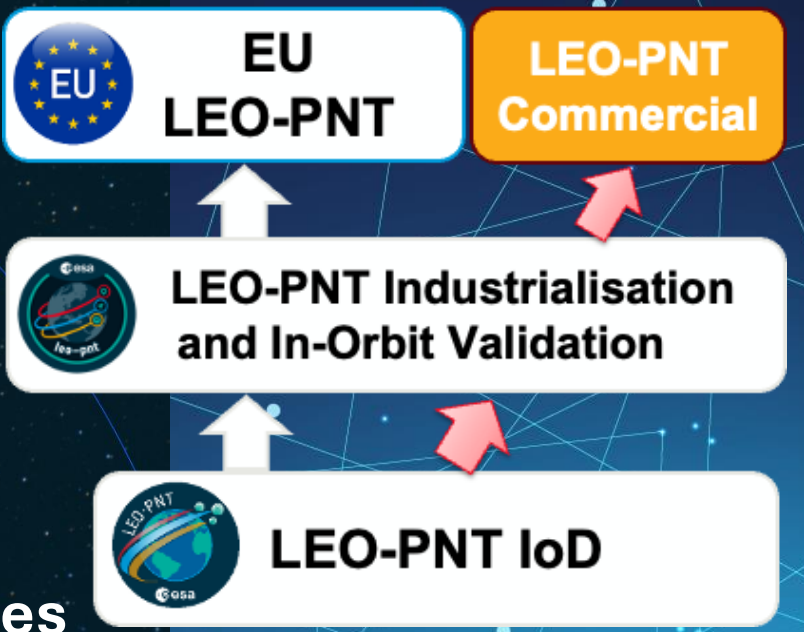


LEO-PNT next phase: Transition to Operational

… from prototyping / demonstration to industrialisation / in-orbit validation

- Many LEO-PNT initiatives at **International level** (including dedicated workshops at UN ICG) in US (Xona, Trustpoint and SDA), China (Centispace and Satnet) and JAXA
- **ESA leading** role with 2 parallel contracts (TAS-F and GMV)
- **Next industrialisation / validation phase** towards an Institutional operational system and/or Commercial service provision.





LEO-PNT – main strategic pillars

Pillar I
Resilience and Robustness

RESILIENT AND ROBUST PNT

User level vs Jamming and Spoofing

BACK-UP PNT System

MEO-independent non-nominal
(if GALILEO is not available)

Pillar II
Galileo/EGNOS Augmentation

PPP Fast Convergence
Urban Performance
NAV Data dissemination

GALILEO / EGNOS SYSTEM

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

Pillar III
New Service Capabilities

2WAY 6G NTN PNT

IoT LOW ENERGY PNT

INDOOR (TIMING, POS, EMERGENCY)

PNT FOR PERSONAL EMERGENCY

Strategic Pillars vs Key Payload Building Blocks

Pillar I
Resilience and Robustness

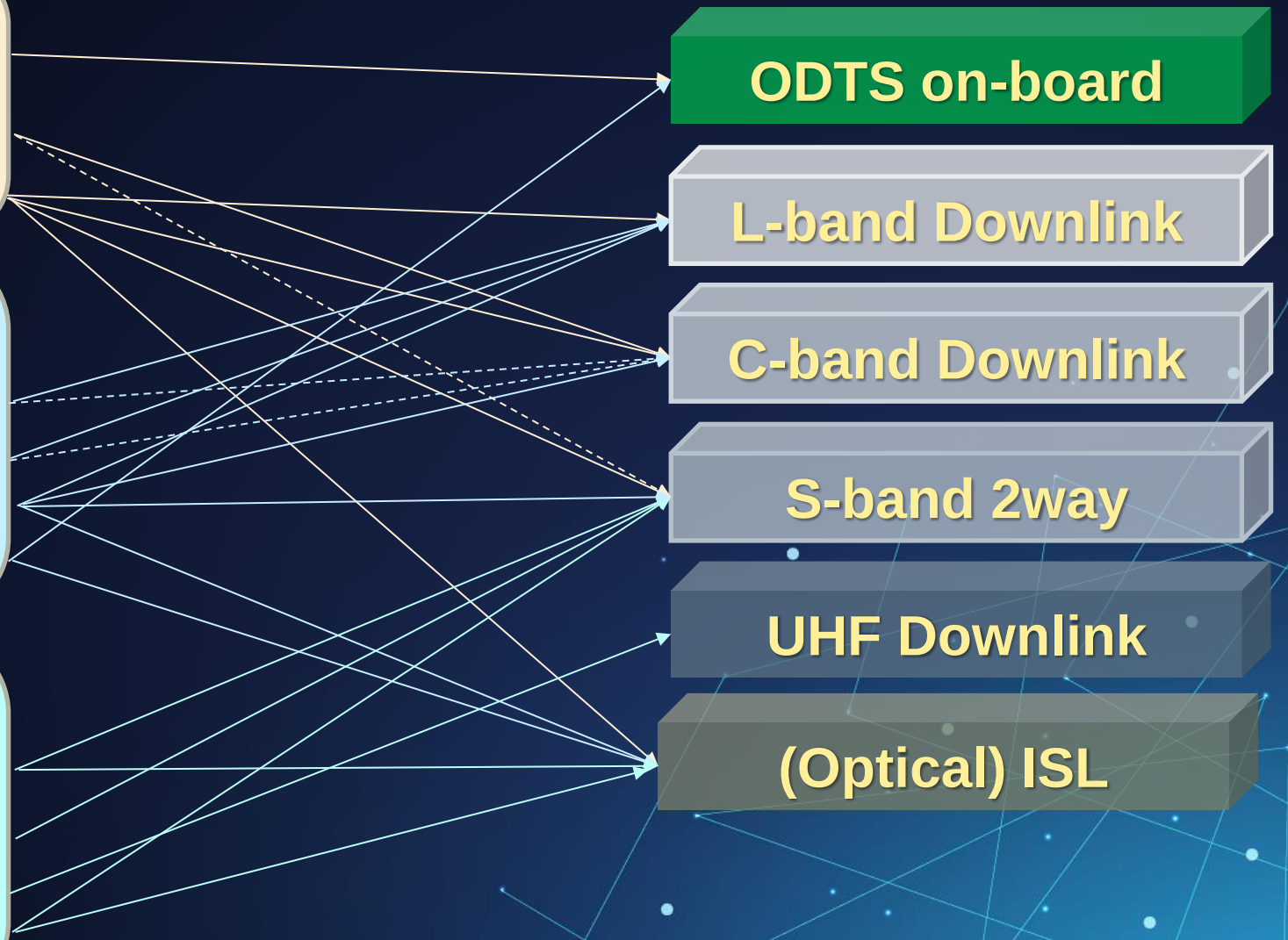
- RESILIENT PNT (@user - jamming / spoofing)
- BACKUP PNT System (MEO indep.)

Pillar II
Galileo/EGNOS Augmentation

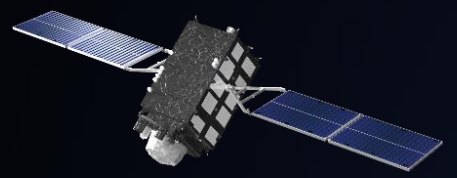
- PPP Fast Convergence
- Urban Performance
- NAV Data Dissemination
- GALILEO / EGNOS SYS OPTIMISATION

Pillar III
New Service Capabilities

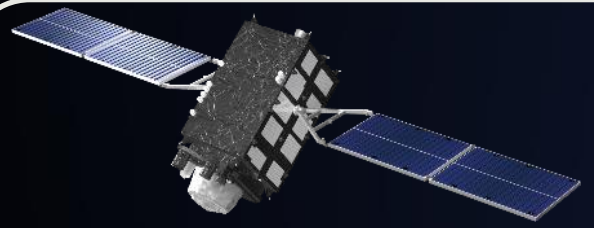
- 2WAY 6G NTN PNT
- IoT LOW ENERGY PNT
- INDOOR (TIMING, POS, EMERGENCY, …)
- PNT FOR PERSONAL EMERGENCY



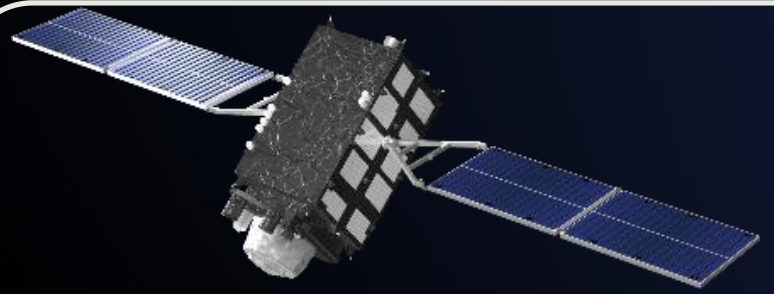
Satellite Classes (Mass / Power / Rec cost) vs Payload Building Blocks



Small: 100-150kg 200-250W
Target ~1Meur/sat rec. price



Medium: 250kg 500-700W
Target ~3-5 Meur/sat rec. price



Large: 300-400kg 750-1000 W
Target ~7-10 Meur/sat rec. price

Urban perfo + fast PPP

Dissaggregated services

ALL Building Blocks All ServicesTogether

- ODTS on-board
- L-band downlink
- C-band downlink
- S-band 2way
- UHF downlink
- (optical) ISL

In order to reach the Satellite Recurrent Price (and lead times), a major effort in Industrialisation / Production capabilities is required

Preliminary Roadmap for EU LEO-PNT
(assumption LEO constellation at 1200km)

CM25

ESA LEO-PNT IoD

2024-2027
10 satellites
Technology TRL increase
In-Orbit experimentation
Frequency Filings
Service demonstration

LEO PNT System Design + Building Blocks + Industrial capabilities & In-orbit validation

2026-2029
~32 satellites
- System Design + Bulding Blocks devp
- Production Industrialisation (incl. dual source)
- Full perfo valid. over Europe 4-6hr/day

EU LEO-PNT FOC1

Data Dissemination and Resilient Timing

2029-2031
TOTAL ~64 sats
- Initial services
- Data diss. / Resilient Timing
- Globally services with at least 1 sat in vew

EU LEO-PNT FOC2

Resilient PNT

2032-2034
TOTAL ~128 satellites
- Resilient PNT globally
- Services with at least 4 sats in view

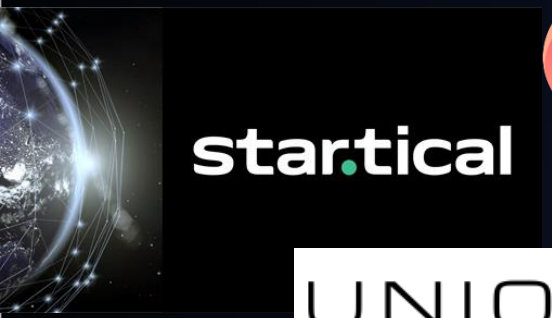
EU LEO-PNT FOC3

Urban Perfo + PPP Fast Converg.

2035-2038
TOTAL ~256 satellites
- Full features for all services including urban and PPP convergence (requiring >>4 sats in view)

LEO-PNT commercial

In addition to the consortia involved in LEO-PNT IoD, there are several initiatives with strong potential to exploit LEO PNT services from commercial point of view:



- Promote access to space for **service provision in the open commercial market** in support of the competitiveness of European industry.
- ESA to drive the definition of **interoperability standards for LEO-PNT** in collaboration with interested regions.
- Business opportunities to the European industry to **supply technology and products** to export programmes.

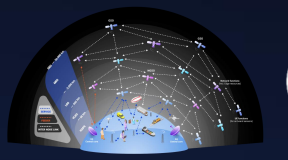
LEO-PNT: main priorities

In order to maintain the **leadership on GNSS**, in view of the ongoing LEO-PNT developments in the world, and in order to **ensure industry readiness at the beginning of next MFF**, the following priorities shall be achieved in 2024-2026 timeframe:

1. To start the elaboration of set of target **mission requirements**, **signal** design requirements and taking into account International s**tandardisation** efforts **under EU leadership**.
2. To engage in **Building Block & Technology** development, verification and qualification.
3. To initiate **Industrialisation** process allowing European industry to be ready to implement a schedule and cost-effective operational EU LEO-PNT.
4. To establish a joint plan between ESA (CMIN25) an EU (Next MFF) for an **integrated EU LEO-PNT vision**.
5. Drive the definition of interoperability standards for LEO-PNT in order to promote **commercial market** in support of the competitiveness of European industry

FutureNAV Component 3: Demonstrators and Supporting R&D

Maintaining Europe's Leadership in PNT



(In-Orbit) Demonstrators and Supporting R&D

Demonstrators and System Testbeds
Optical Demonstrator (OpSTAR)
Demonstrator for Integrity Concepts beyond Aviation
Demonstrator of Lunar Reference Stations (NOVAMOON)

NAV R&D and Pre-developments in support to Demonstrators
System Preparatory Studies
Pre-developments for future (IOD) demonstrators
Navigation Payload Disruptive Technologies for IOD
Machine Learning / Artificial Intelligence Technologies for PNT
Optical and Quantum System Studies and Predevelopments

Fully coordinated with the ESA Strategy on Quantum and AI technologies

Scouting the interest of European industry

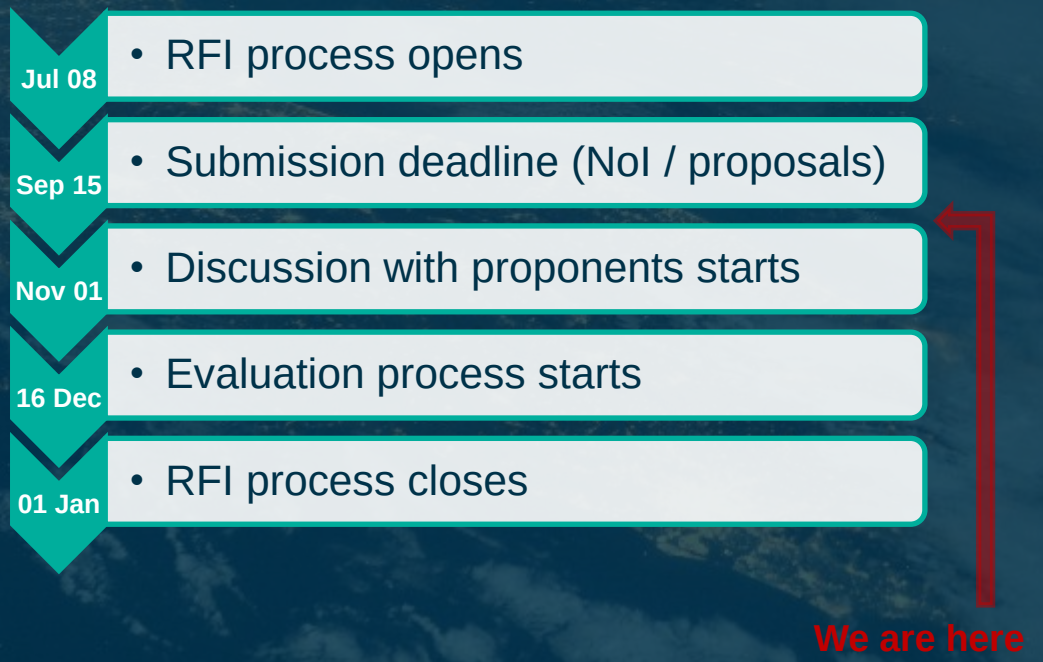
ESA has thus issued a Request for Information (RFI) to call upon European Industry and Research community to:

Submit interest to lead/contribute to **existing demonstrators** and **ideas for future demonstrators and disruptive technologies**, with the following high-level objectives:

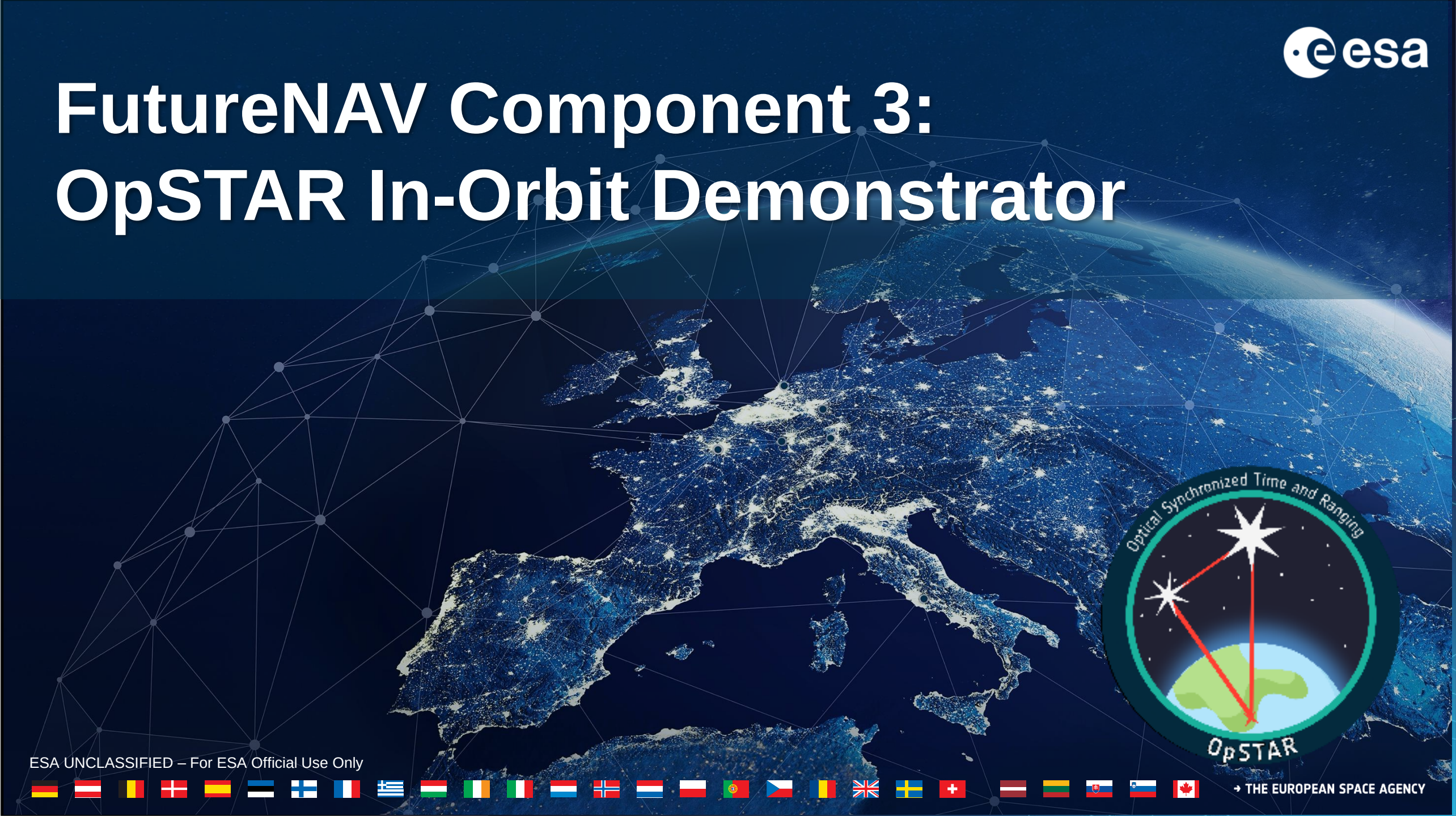
- ✓ **Objective 1**: Confirm interest for existing IODs
- ✓ **Objective 2**: Gather ideas for future IODs
- ✓ **Objective 3**: Collect R&D activities supporting Objectives 1/2

Objectives of the Call

- To **foster and enhance Europe's leadership in GNSS** through innovation
- Submissions are accepted via ESA's OSIP, with a process following the schedule below:



FutureNAV Component 3: OpSTAR In-Orbit Demonstrator

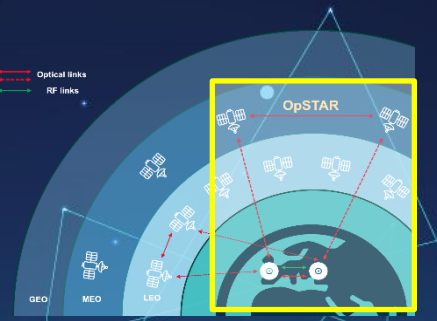


OpSTAR (Optical Demonstrator)

Demonstrator of Optical Inter-Satellite Link capabilities for PNT

In-Orbit Demonstrator (Technology validation and exploration of use cases)

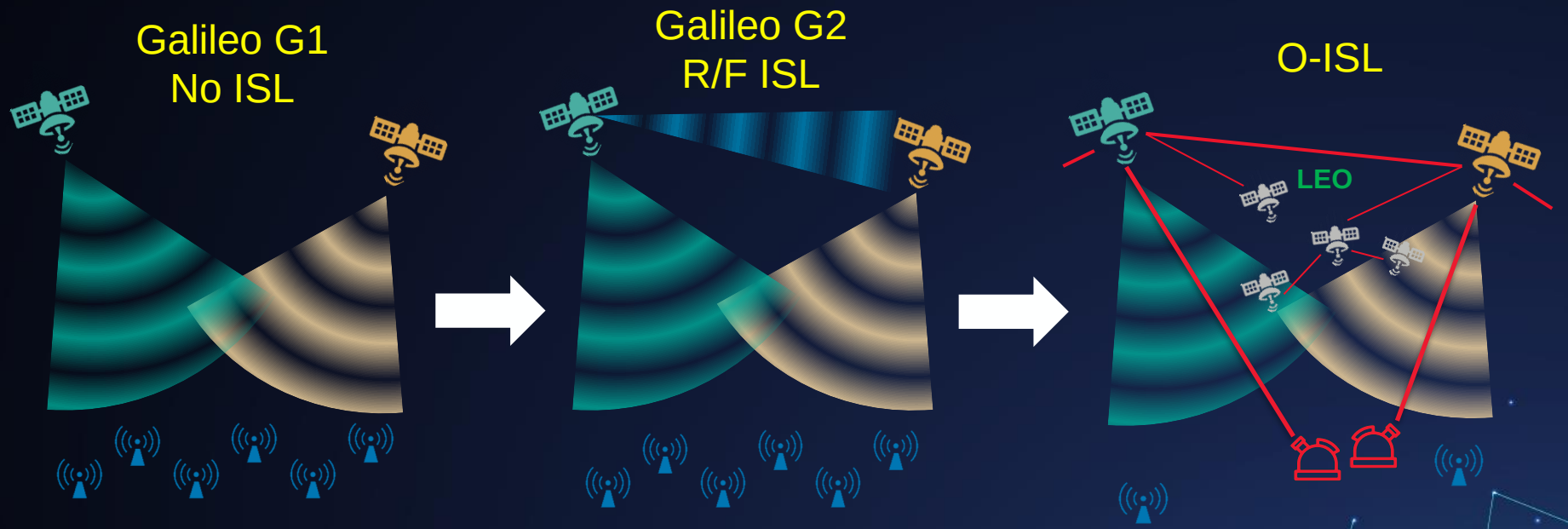
Prior to In-Orbit Validation (Service Validation before extension to operational)



IOD Mission Objectives:

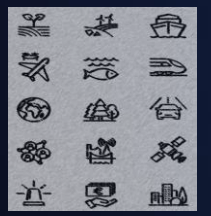
- ✓ Demonstrate the use of optical links for PNT (time synchronisation & ranging)
- ✓ Demonstrate and measure the significant performance improvement at system/user level
- ✓ Assess benefits of a new system architecture based on optical links
- ✓ Develop (European lead) open standards for PNT O-ISL (physical, data link and network layers)
- ✓ Mature PNT specificities of the technology for use in operational infrastructure at earliest opportunity with minimal risk

Continuous improved Ranging and Timing towards Optical



Optical Technology Benefits For GNSS

- ✓ Increased Resilience and System Autonomy
- ✓ Not subject to frequency coordination and regulations
- ✓ Inherent high data transfer capabilities
- ✓ First step towards application of quantum technologies for GNSS
- ✓ Enabler of GNSS multi-layer architecture (i.e. MEO-LEO)



- ✓ Improved PNT performance
- ✓ Faster PPP convergence
- ✓ "Continuous" Navigation Data Dissemination

OpSTAR Preliminary Architecture

GNSS L-Band Rx

GNSS L-Band Rx

Optical Link

Optical Space Segment

S-Band TM/TC

L-Band (E1/E5)

Optical Link

Optical Link

Optical Link

Optical Link

L-Band (E1/E5)

L-Band

INTERNET

Remote Optical
Ground Stations

Satellite
Control System

Fibre Optic Link

Communication & Synchronisation

INTERNET

Optical PNT
Test User Range

Launch Services

Orbit & Time
Reference System

Optical System Test Bed

Preliminary Roadmap for OpSTAR implementation

OpSTAR
Phase A/B1

CM25

OpSTAR IoD implementation
Phases B2/C/D/E

2026-2029
- 2 satellites
- Dual source LCRT for ground interoperability validation
- 2 Optical Ground Stations
- System Engineering
- Optical Testbed (development)
- Optical PNT Test User Range (development)

NEXT MFF

Completion of OpSTAR IoD implementation

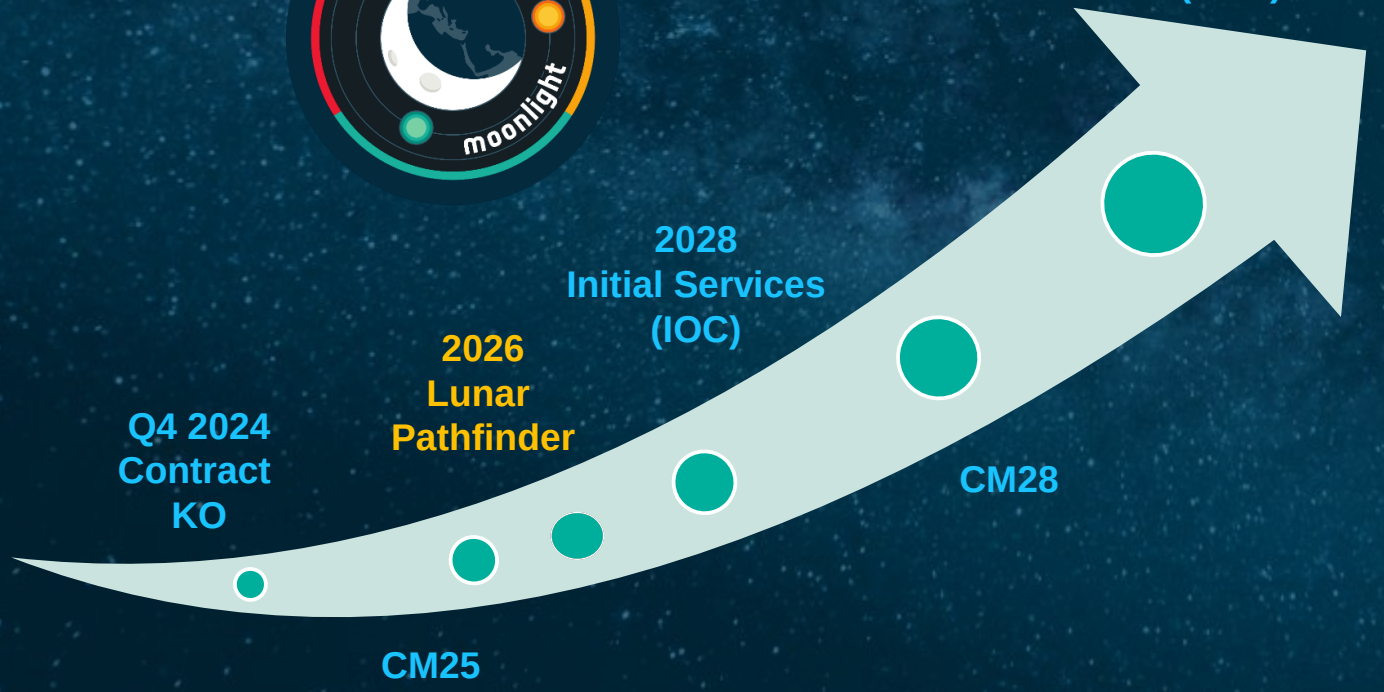
2029-2031
- Optical Testbed (validation)
- Optical PNT Test User Range (validation)
- Satellite Control as service
- 3 years operations and experimentation

Readiness of optical technology for E-GNSS

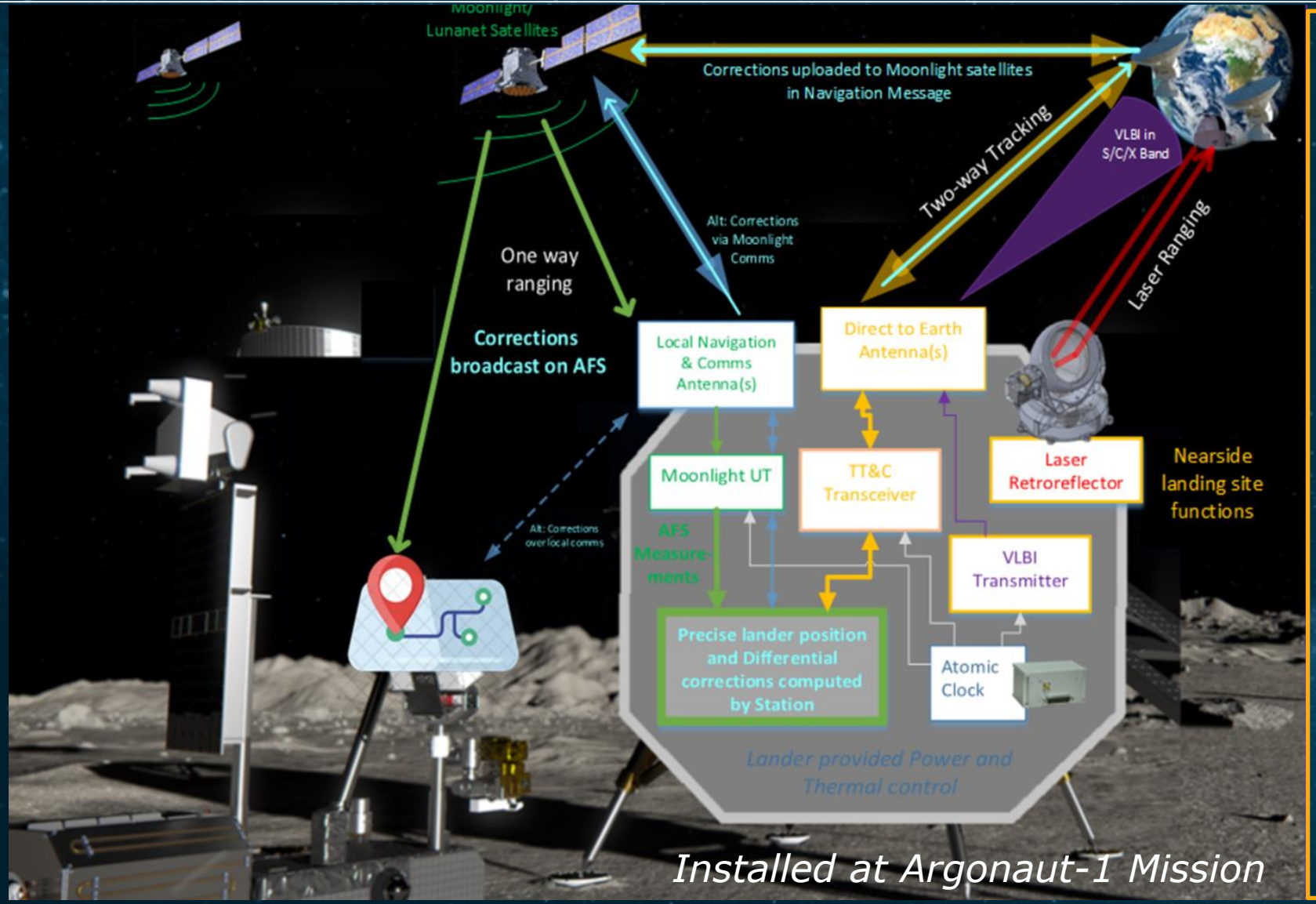
FutureNAV Component 3: NOVAMOON In-Orbit Demonstrator

PRIORITY TO MAINTAIN MOONLIGHT SERVICES ROADMAP

Establish European Communication & Navigation capabilities through a commercial Service Provider to serve institutional and commercial Lunar explorers



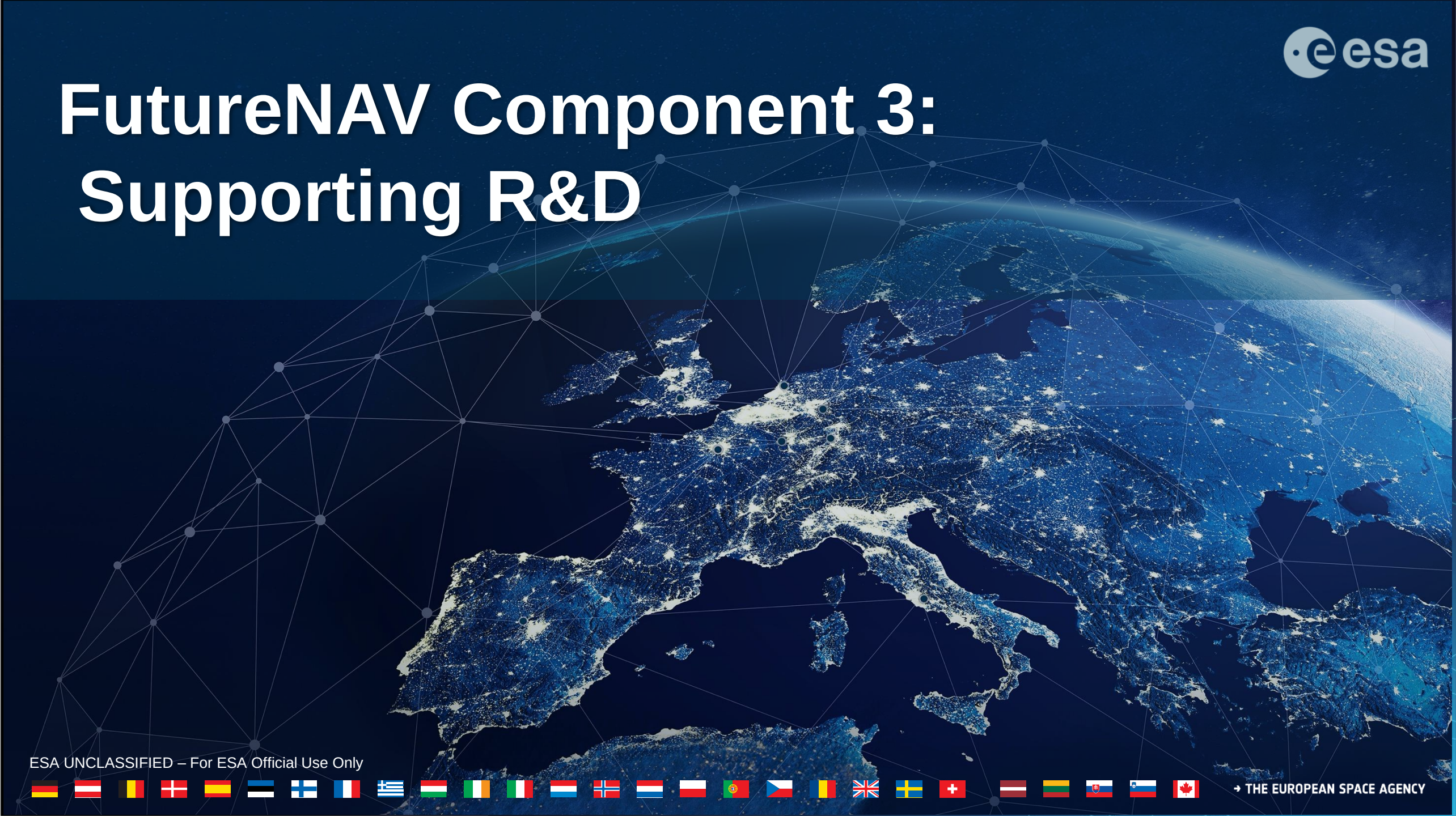
NovaMoon System Architecture



Installed at Argonaut-1 Mission

1. A Moonlight (and LunaNet) local differential station with surveyed antenna, two independent local LunaNet receivers, Local Differential computation processor and multiple communication links
2. First atomic clock ensemble and synchronisation unit on Lunar Surface
3. Four co-located geodetic techniques on-board on lunar surface:
   - GNSS PNT (Moonlight)
   - VLBI transmission
   - Advanced Laser Ranging Retroflector(s)
   - Two-way Direct To Earth

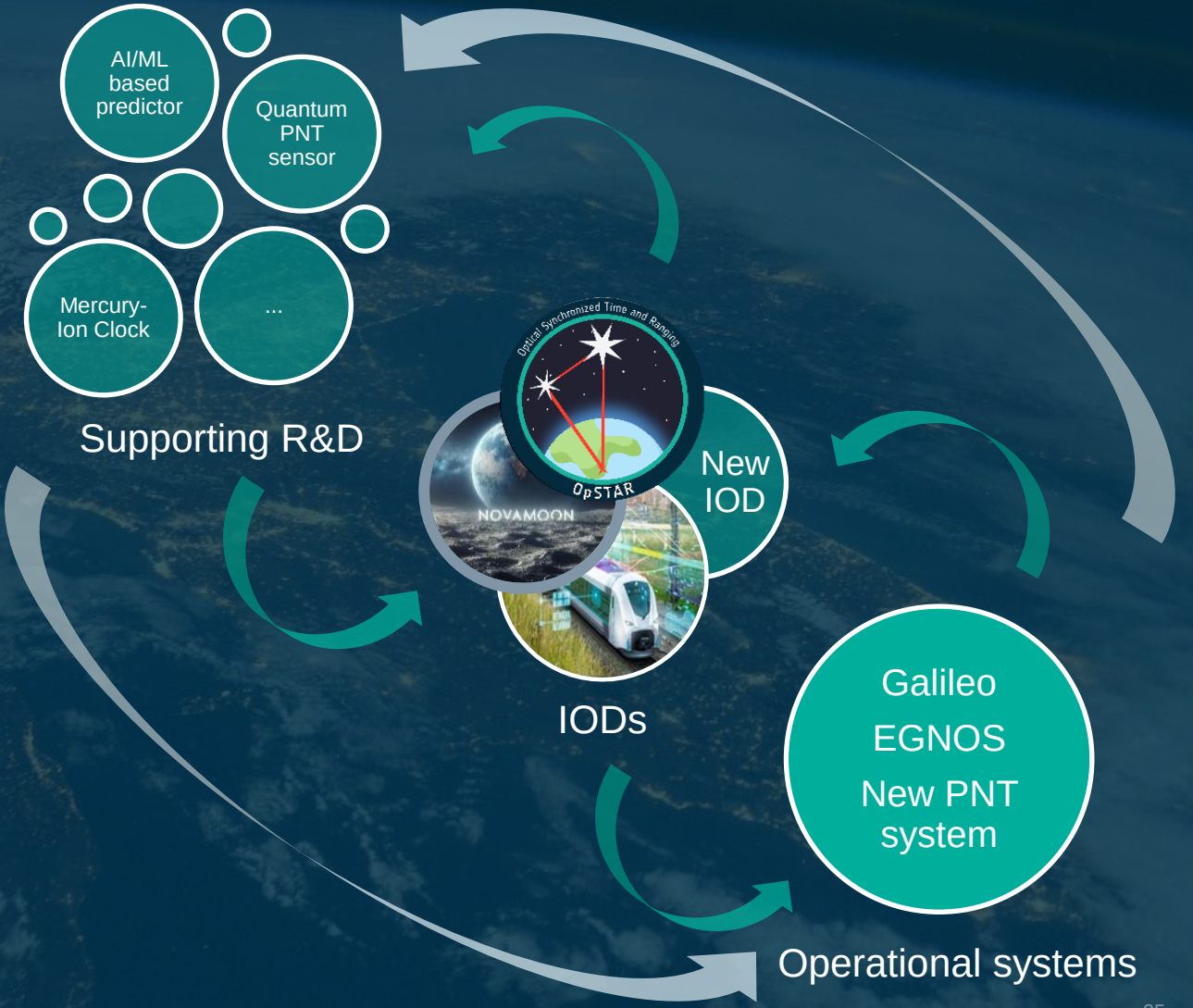
FutureNAV Component 3: Supporting R&D



Supporting new IODs with R&D and pre-developments

Why does Europe need to support new IODs with R&D and pre-developments?

1) **To build new PNT technologies and concepts to be demonstrated before introduction in operational systems**
2) **To accelerate the adoption of these technologies**, catering to the ever increasing and faster needs and opportunities arising within the PNT market
3) **To raise the global competitiveness of European industries**, turning pure academic and research efforts into space qualified products, bringing them a step closer to incorporation into operational systems



CONCLUSIONS

- PNT largest downstream space applications market
- ESA vision to secure European PNT leadership and competitiveness
- NAVISP Phase 4, GENESIS completion, LEO PNT Industrialisation and In-Orbit Validation phase, FutureNAV Component 3
- LEO-PNT next phase will focus on Industrialisation process allowing European industry to be ready to implement a schedule and cost-effective operational systems institutional (EU) or commercial.
- NAV Demonstrators concept confirmed by RFI scouting
- 90% new initiatives