

Moonlight Programme Development Status



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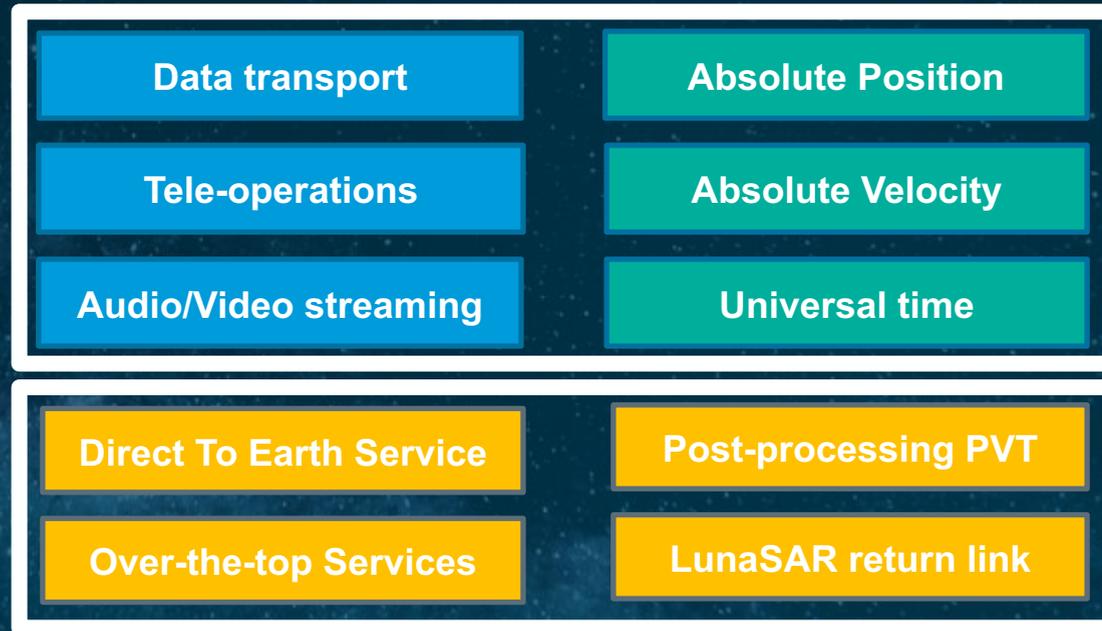
Session Lunar PNT Frameworks & Systems
2nd Joint ICG-IOAG Multilateral Cislunar
PNT Workshop, Vienna 10 February 2026



Moonlight Lunar Communication & Navigation System

 **TELESPAZIO**
a LEONARDO and THALES company

Partnership between ESA and a European consortia led by Telespazio Italy
ESA supporting infrastructure development and acting as Anchor customer



To provide dedicated constellation over Moon providing **interoperable Communications and Navigation Services** to support the current and next generations of **institutional and commercial Lunar explorers**

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Moonlight LCNS High-level Mission and Service Drivers



Supporting
Commercial &
Institutional Missions



Interoperable
LunaNET
Standards



Staggered approach
aligned to market
IOC 2029
FOC 2031+



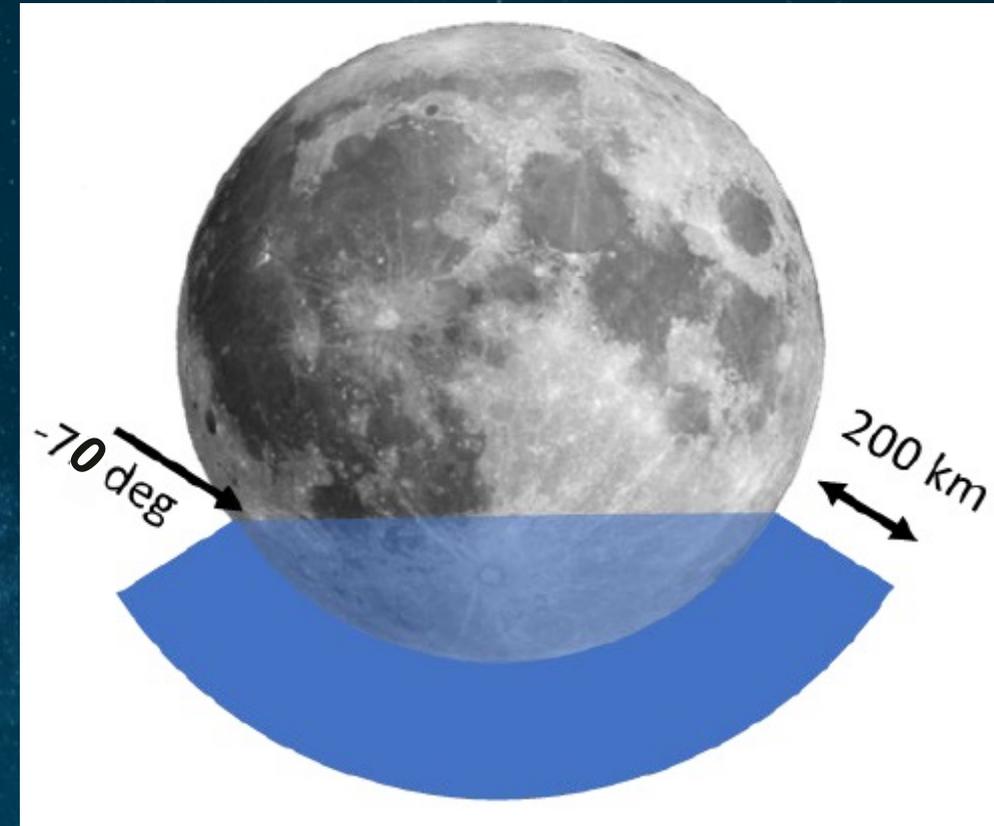
A Scalable System



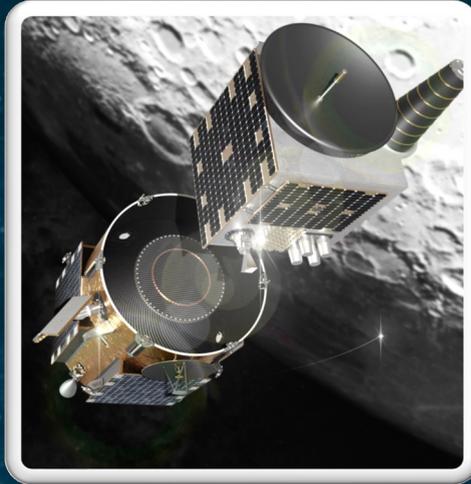
Supporting all Mission
Phases



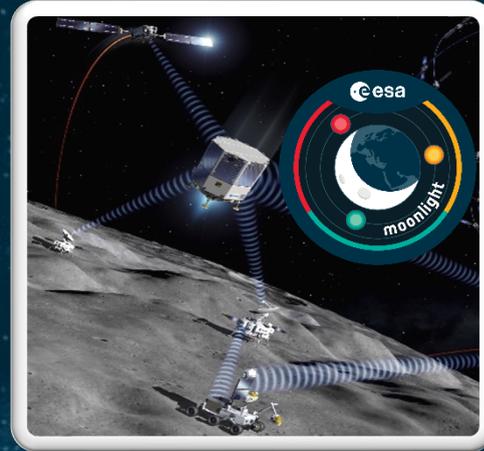
Optimised
For South Pole
services
[70-90° South]



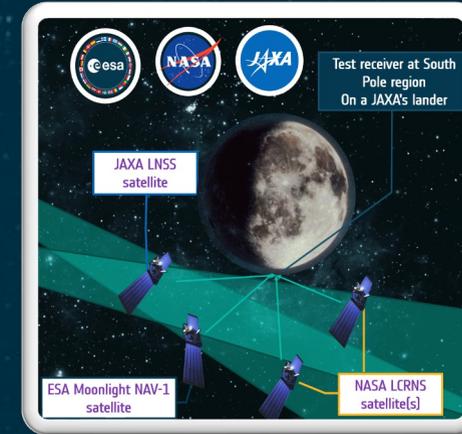
ML part of ESA Roadmap For Lunar and Space Exploration PNT



Lunar Pathfinder

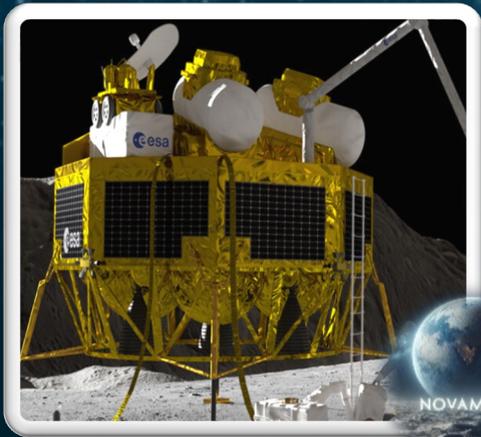


Moonlight IOC / FOC



LunaNet interoperability

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NovaMoon



MARCONI PNT Demonstrator



SSi Node-1 Pathfinder

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Moonlight Programme Consortium



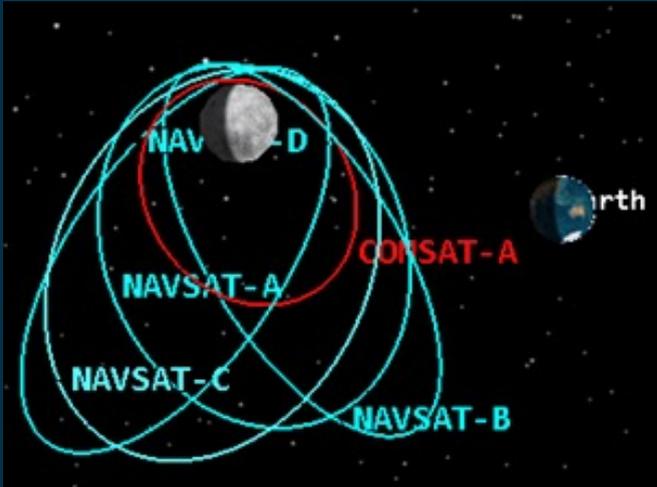
- ✧ The Lunar Communication and Navigation Services (LCNS) program is part of ESA's MOONLIGHT initiative, with Telespazio S.p.A. acting as the prime contractor and overall system integrator.
- ✧ LCNS program is currently in phase B2 and includes the development, In Orbit Validation and Operations.

✧ The consortium includes many European companies:

- Viasat and Hispasat support Telespazio in the service provisioning and system engineering
- Viasat has the responsibility of COM E2E Com Design including Com satellite procurement
- Thales Alenia Space Italia has the responsibility of NAV E2E Design including Navigation Satellites procurement, and the procurement of the Navigation Management Center
- Other 2nd level contractors involved are MDA, Telespazio UK, Telespazio Iberica.
- Universities and Research Centerers support the design and BD activities: SDA Bocconi, POLIMI, CRAS, and Sapienza

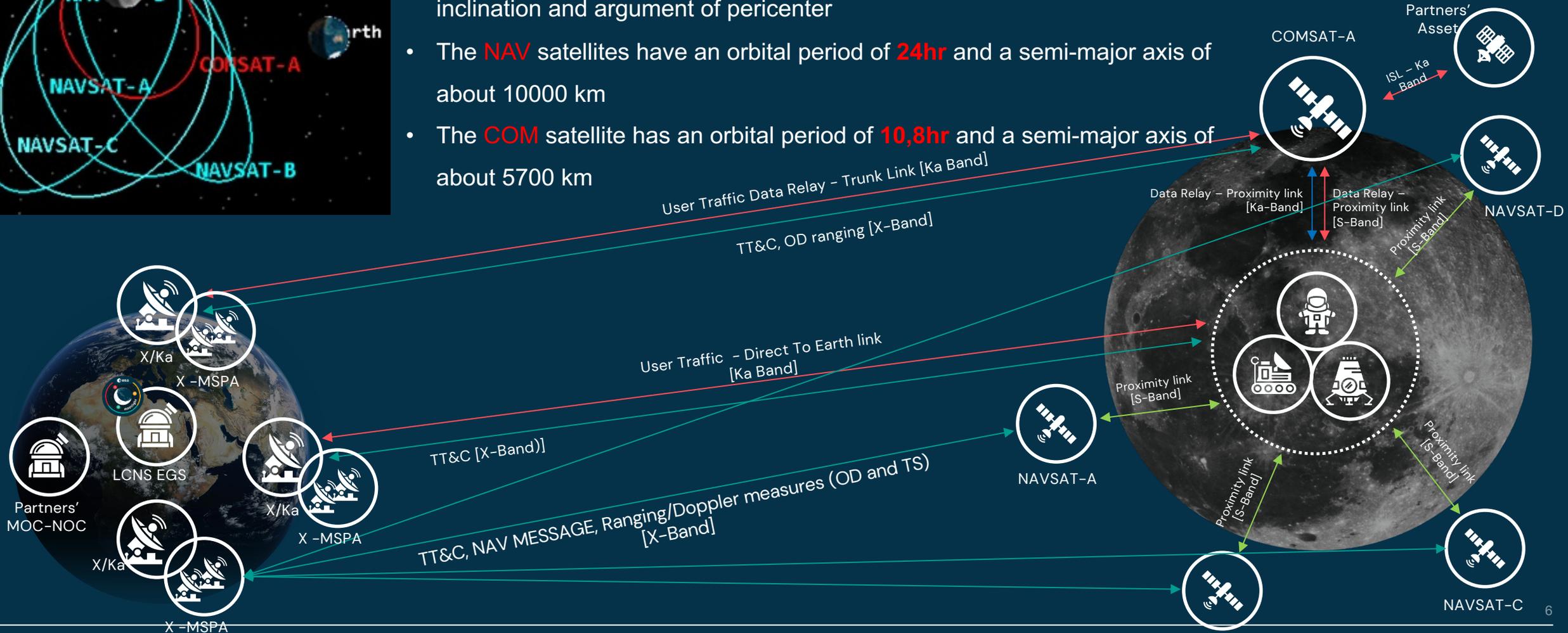


Moonlight SYSTEM ARCHITECTURE - OVERVIEW



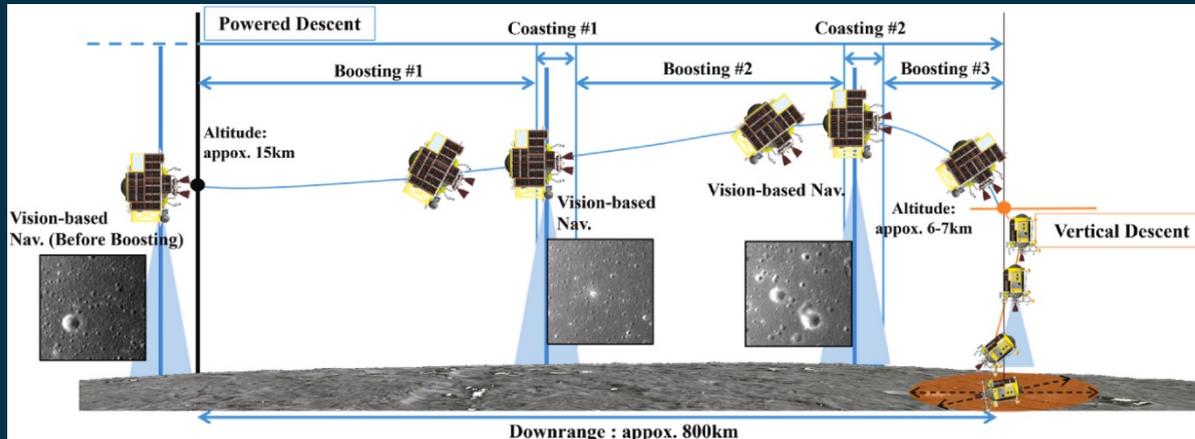
LCNS orbital configuration of Space Segment:

- Elliptical Lunar Frozen Orbits (ELFOs) to obtain a constant eccentricity, inclination and argument of pericenter
- The NAV satellites have an orbital period of **24hr** and a semi-major axis of about 10000 km
- The COM satellite has an orbital period of **10,8hr** and a semi-major axis of about 5700 km



Use Cases

- Surface vehicle (rover) or static user at lunar south pole
- Ascending/Descending vehicle (e.g., lunar lander) at south pole
- LLO (Low Lunar Orbiters) which have an orbit in the SV2 (i.e. within 200 km from the lunar surface), with optimized performances above the lunar south pole.



Service Volumes (SV) definition:

SV1 – South Pole (surface of the Moon -75° - 90°)

SV2 – South Pole (0Km – 200Km same as SV1-SP)

The other service volumes will be served in best effort and with the following order of priority: SV1_FS, the rest of SV1, the rest of SV2, SV3 (lunar orbits with an altitude ≤ 5000 km) and SV4. (lunar orbits with an altitude ≤ 70000 km)

Moonlight – Navigation End to End system design drivers



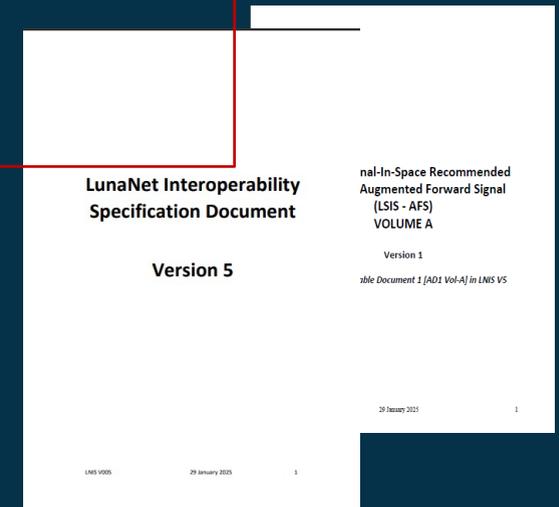
The main Navigation performances are:

- ✦ OWR Real time SISE positioning. 10 m at least 95% of the time over any 24 hours
- ✦ OWR Real time SISE velocity. 1,5 mm/s at least 95% of the time over any 24 hours
- ✦ OWR service availability. 95%, computed over 3 months
- ✦ PVT Service availability 95%, computed over 3 months
- ✦ PVT accuracy, depending on the use case

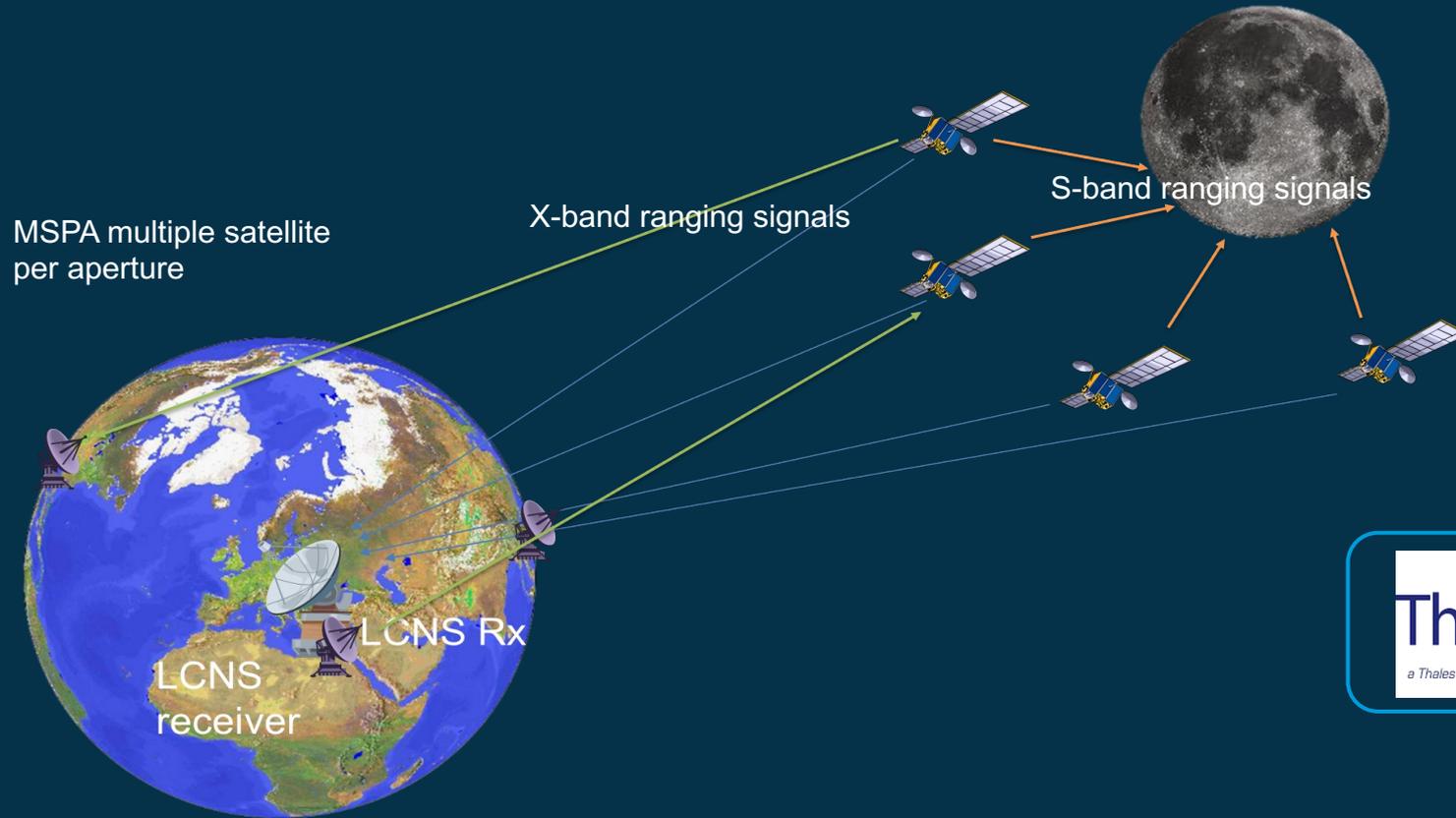
- Definition of a system time
- Definition of a ground architecture to collect ranging measurement for OD and TS
- Definition of a SISICD and message uplink

- ✦ How to define a common system time?
- ✦ How to define common reference frames?

Interoperability constraints (**Lunanet**)



MOONLIGHT – NAV Chain Architecture



E2E LCNS Design Authority

E2E LCNS NAV Design
NAV Satellite Provider

LCNS User Segment
NAV Terminal

Moonlight achieved the Close-out of the system PDR for the Navigation E2E chain including segments

- ✧ Earth Ground Segment (EGS)
- ✧ Lunar Space Segment (LSS) NAV
- ✧ Lunar User Segment (LUS) NAV

And subsystems:

- ✧ LSS NAV including: NAV Payload, TT&C, Avionics, Electric Power System, Harness, Structure, Thermal, Propulsion (on going)
- ✧ EGS including: Navigation Management Centre (NMC), Ground Stations Network (GSN) (step#1), Service Management Centre (SMC) (step#1)

Mission Operation Centre (MOC) and Network Operation Centre (NOC) PDR for Navigation E2E Chain is on going

Program is progressing toward CDR, a first step at segment and system level is foreseen to be achieved within Q4 2026

PFM NAV available for Launch Q4 2028 (IOC)
FM 2, 3, 4 available for Launch Q2 2030 (FOC) (TBC)

- ✧ **Frequency Filing for the NAV Mission already submitted (see dedicated presentation)**

LUS



LUS NAV

- Exploits Qascom heritage on NAV RX for MOON
- Implements authentication of the nav message
- Compliant to LSIS V1
- PFM ready in 2028

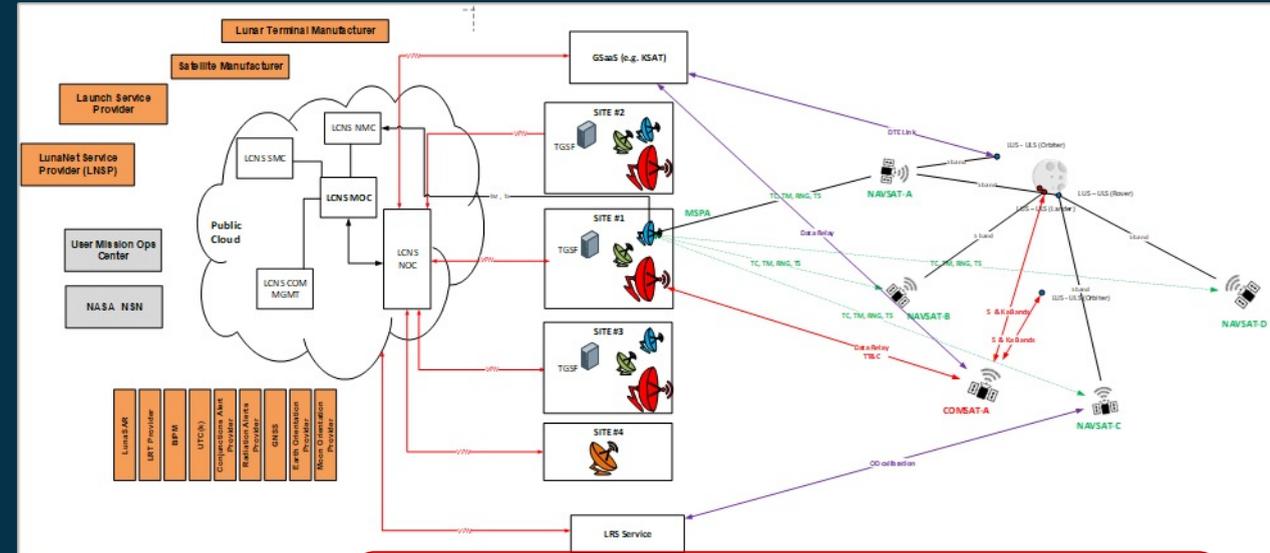
LSS



LSS NAV

- Exploits NIMBUS platform heritage
- Nav Payload
- On board atomic clock (MiniRafs)
- Trasponder for OD ranging and TWTT for clock sync

EGS



EGS

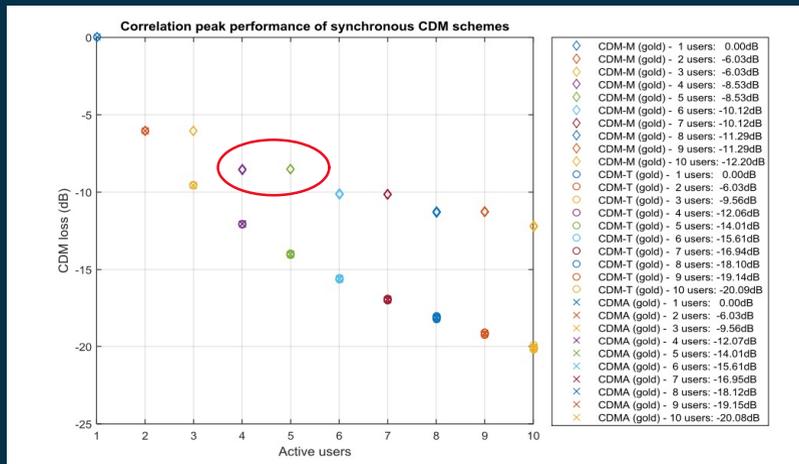
- GSN network to implement MSPA concept for TM, TC, OD ranging and TWTT
- Generation of the LCN5 system time (TGSF) and the relation to LRT and UTC
- NMC navigation management center
- GaaS to improve service availability and NAV Contingencies Management

MSPA

The TT&C link works with a single ground antenna per site for TM/TC. It is also used for ranging and Doppler measurements.

This concept is called “Multi-Satellite Per Aperture” (MSPA), which is based on:

- CDM-M transmission of Telecommands/ Nav messages from ground;
- CDMA reception of satellite Telemetries on ground;



Thanks to MSPA, LCNS has been designed to fully support the Navigation satellites operations and provide the Navigation services with a constellation of 4/5 satellites by using a single ground antenna of 76cms of diameter per site.

MiniRAFS (Mini-Rubidium Atomic Frequency Standard)

The NAVSATs are equipped with a frequency standard which is the realization of the LCNS system time (LST) on-board. The offset between the time on-board LST is estimated on-ground and broadcasted to the users through the navigation message.



On the basis of a trade-off considering performances MiniRAFS were selected maintaining the service provision within specification, while granting both a contained SWaP and cost.

Interoperability and international cooperation

Standards and International cooperation

LCNS RF communication and Navigation links adhere to the International Communication Systems Interoperability Standard (ICSIS), developed by an international body to enable interoperable, cross-supportable, and compatible communications between space vehicles and systems, ground infrastructure, and lunar assets.

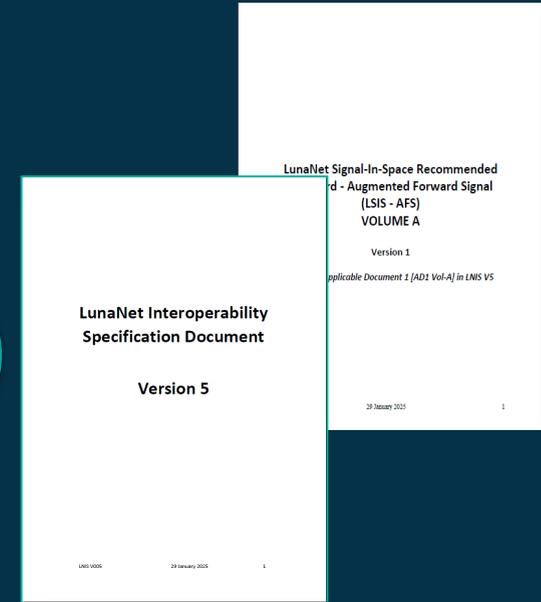
The ICSIS is compliant with Interagency Operations Advisory Group (IOAG), Space Frequency Coordination Group (SFCG), and Consultative Committee on Space Data Systems (CCSDS) standards and recommendations.

Lunanet

- LCNS will provide services included in LNIS, it will guarantee interoperability with the other LNSP, will conform to the LunaNet framework of mutually agreed-upon standards, protocols, and interface specification that enable interoperability.
- The evolutive approach as reported in the introduction of LNIS, proceeding through incremental instantiations of the system of systems, is followed in the setup, which will evolve undergoing a progressive deployment of the communication and navigation services from the IOC to the FOC phase of LCNS



Be prepared for demonstration and coordinate service provision with other Commercial Partners and Agencies



There are some **critical standards** that have an impact on the realization of the system, among these the need to evolve and standardize the **proximity link**, and, fundamental for the deployment of the navigation services, the ones for the **Lunar Reference Systems and Frames**, and the definition of a **Lunar Reference Time**.

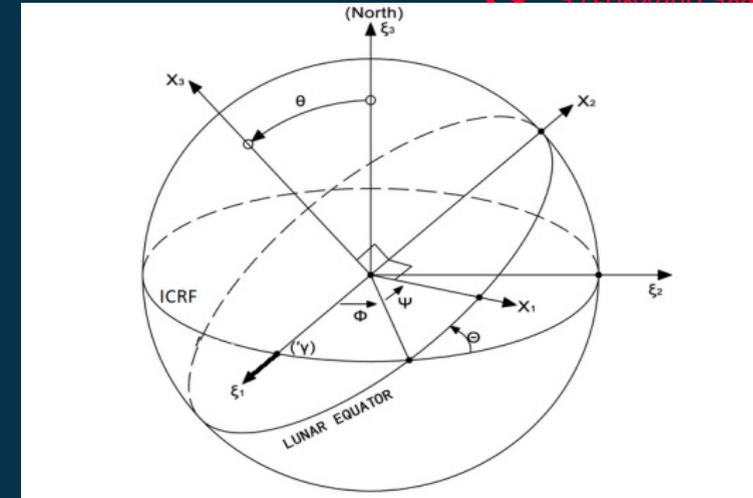
Lunar reference frames and time

Lunar reference Frames

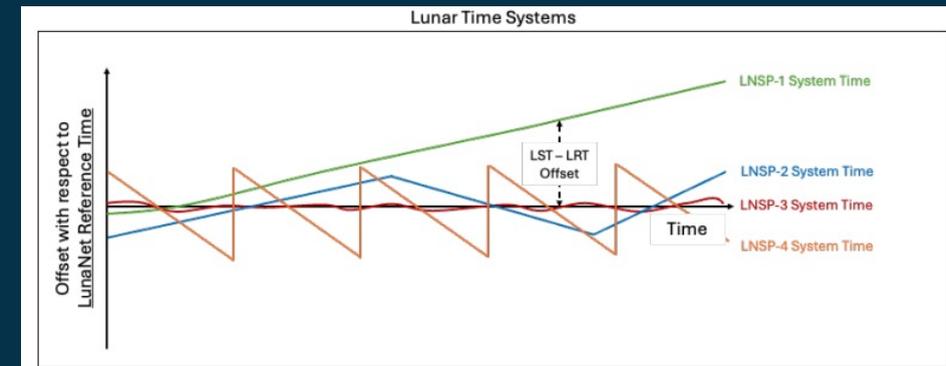
- PA (Principal Axis) is currently selected for operational navigation activities
- The system foresees an interface for reference frames information provider
- Optimisation activities are ongoing to **fit the reference frames conversions** inside the LCNS navigation message:
 - **ILRF(PA) → LCRF** (Lunar Celestial Reference Frame)
 - **LCRF** (Lunar Celestial Reference Frame) → **GCRF** (Geocentric Celestial Reference Frame)
- Flexibility is granted through the PA → MER conversion

Lunar Reference Time

- To ensure LNSP systems are interoperable (mainly for the delivery of PNT services), service products (i.e., AFS time of transmission message) need to be referred to a common time scale - LunaNet Reference Time (LRT).
- If there is an offset between LNSP System Time (LST) and LRT, the LNSP shall implement a mechanism to estimate this offset and disseminate (e.g., through AFS) it to the user.
- LCNS will disseminate LST – UTC offset.

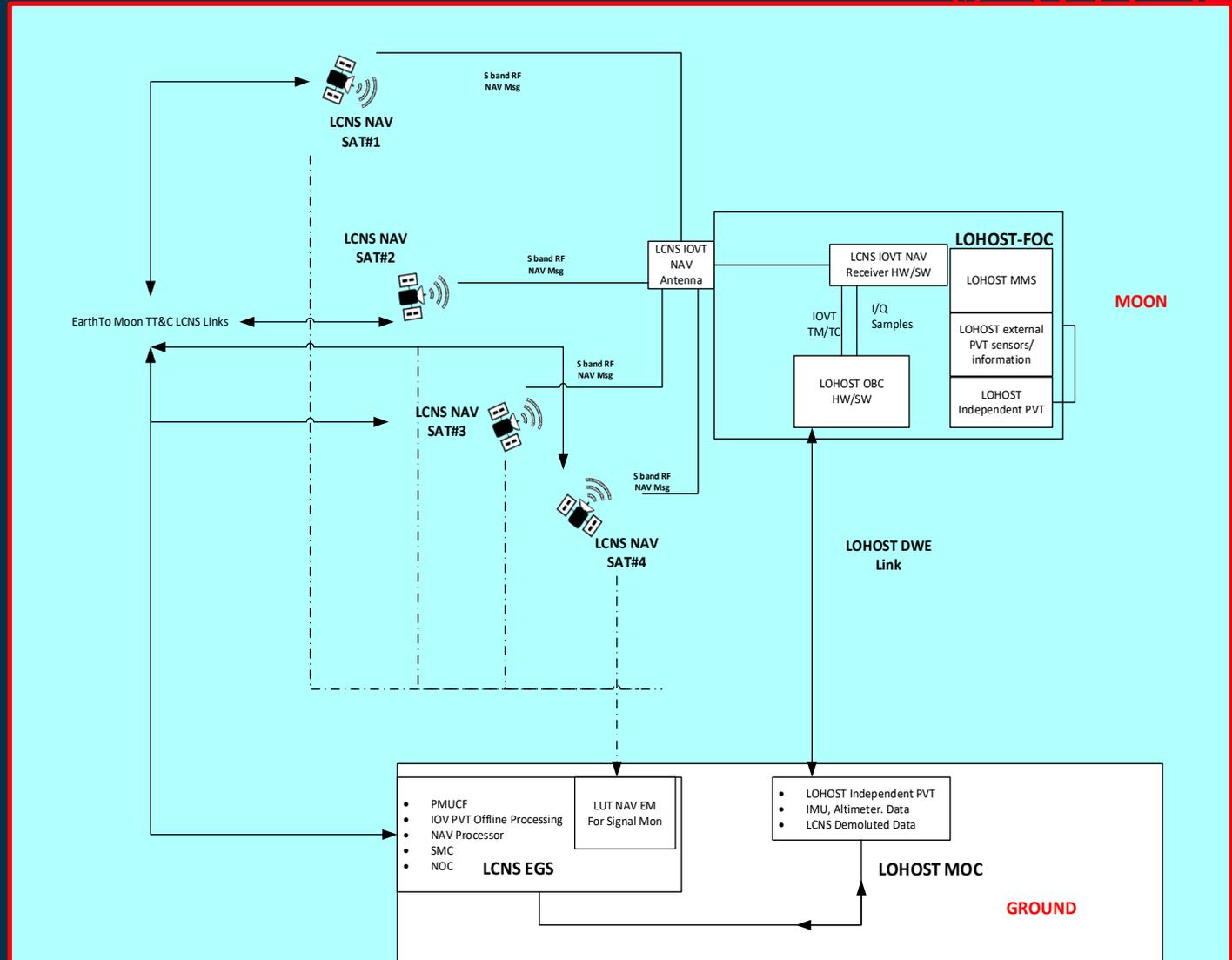


Actually the first version of «Lunar Reference System and LunaNet Reference Time System Standard» has not been released.



In Orbit Validation (baseline and Demo Mission)

- LOHOST, a LLO Orbiter, will accommodate the IOVT (In Orbit Validation Terminal)
- The IOVT is the PFM of the NAV terminal used for LCNS NAV service validation
- A NAV terminal EM is used on ground for user onboarding
- One NAV terminal EM is deployed at Fucino for NAV signal monitoring
- The LANS Interoperability Demonstration could contribute to LCNS validation activities, due to interoperability, granted by LunaNet standard adoption



Thank you!



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