

# LunaNet Overview and Interoperability for Lunar PNT

## Contributors:

Cheryl Gramling, NASA

Juan Crenshaw, NASA

Richard Swinden, ESA

Floor Melman, ESA

Cosimo Stallo, ESA

Masaya Murata, JAXA

11-13 February, 2025

ICG-IOAG Cislunar PNT Workshop

Vienna, Austria

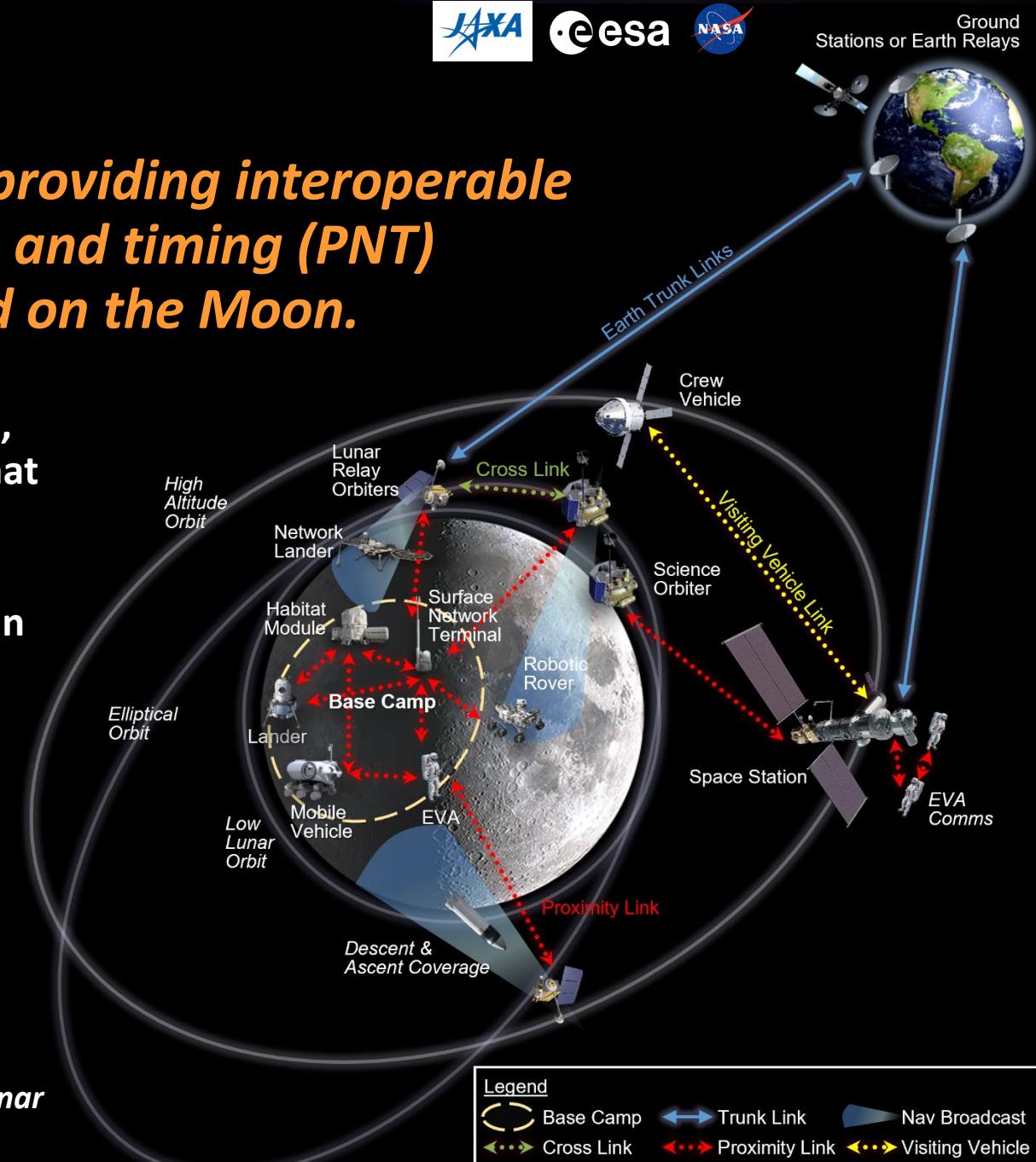
- LunaNet
- LunaNet Interoperability Specification
- LunaNet PNT Services
- LunaNet Service Provider Updates

# What is LunaNet?

**LunaNet is a set of cooperating networks providing interoperable communications and position, navigation, and timing (PNT) services for users in transit to, around, and on the Moon.**

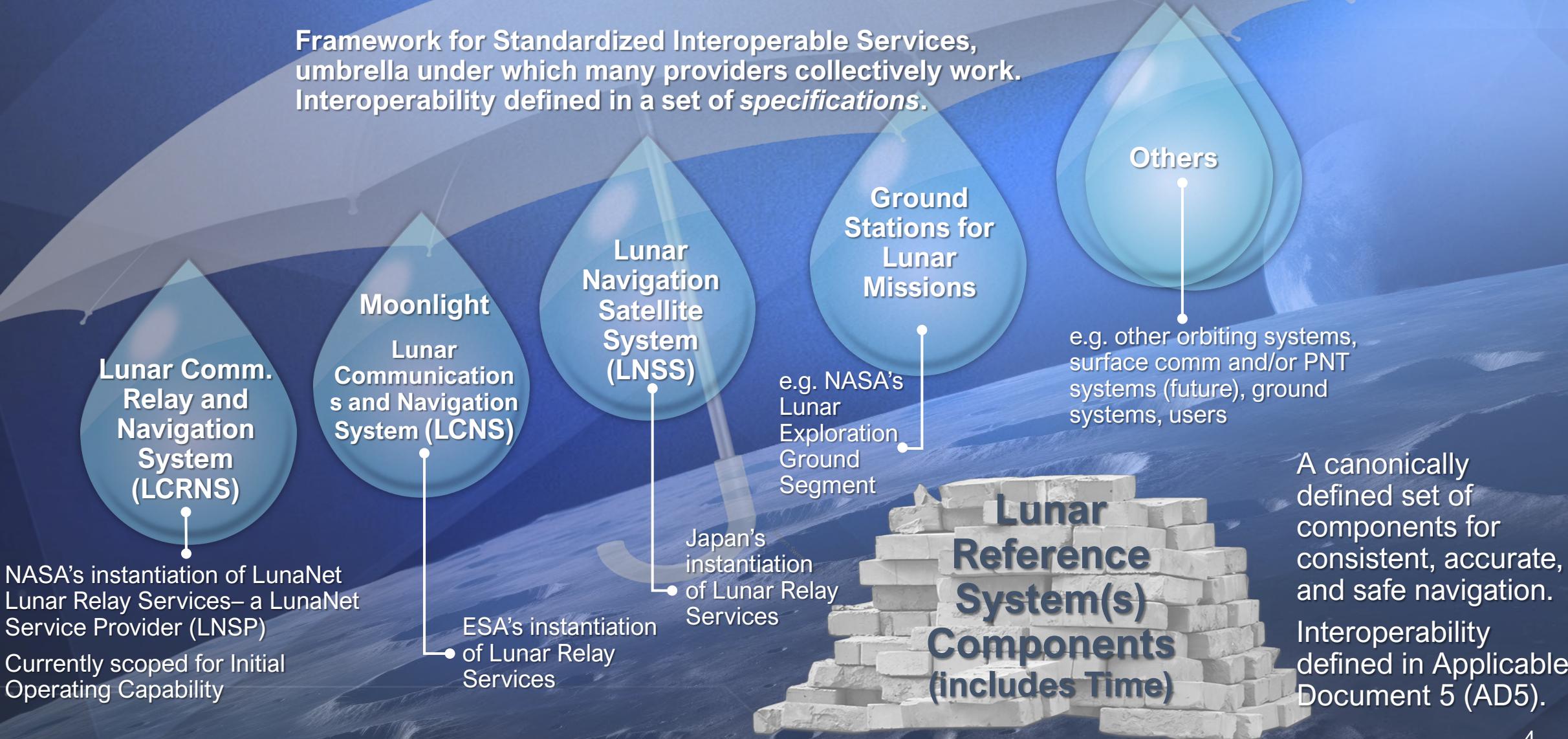
- Based on a framework of mutually agreed-upon standards, protocols, frequency bands, and interface requirements that enable interoperability.
- Allows many lunar mission users to engage the services of diverse commercial and government service providers in an open and evolvable architecture.
  - Service-Oriented
  - Scalable
  - Open
  - Resilient
  - Secure
  - Extensible

LunaNet consists of Earth Ground Stations (for Direct with Earth links), lunar orbital relays (lunar proximity and Earth trunk links), and surface assets:



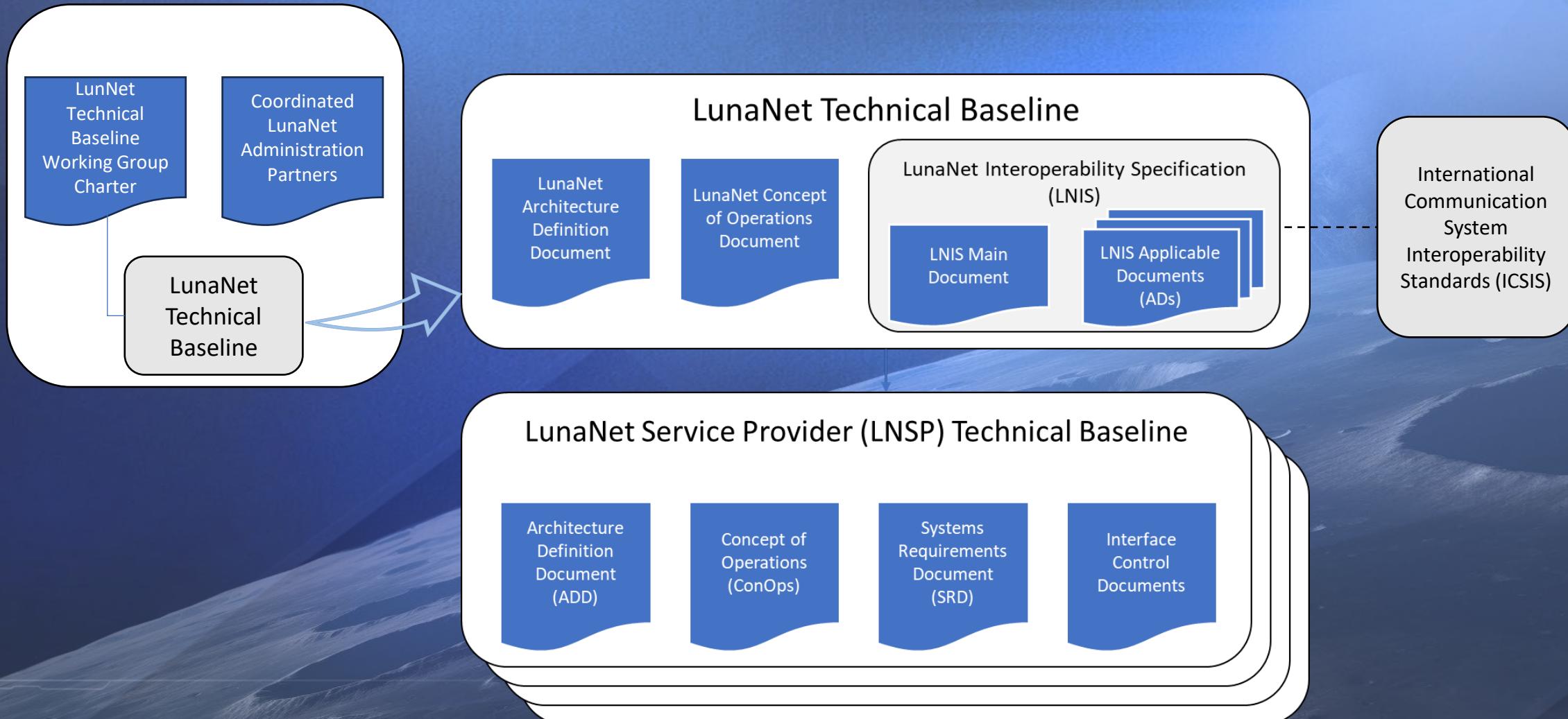
## LunaNet

Framework for Standardized Interoperable Services,  
umbrella under which many providers collectively work.  
Interoperability defined in a set of *specifications*.



A canonically defined set of components for consistent, accurate, and safe navigation.  
Interoperability defined in Applicable Document 5 (AD5).

LunaNet Interoperability Specification (LNIS) is part of the LunaNet Technical Baseline set of documents.



# LunaNet Interoperability Specification



## LunaNet Interoperability Specification (LNIS)

- A set of mutually agreed-upon specifications of standards, protocols, and interface requirements that enable interoperability.
- Provides a basis for operation of a network capable of interoperating with other LNIS-compliant networks.
- Being developed cooperatively with international partners through the LNIS Working Group.
- **Besides the main document, includes a set of Applicable Documents:**

- AD1 Volume A LunaNet Signal-In-Space Recommended Standard (LSIS) Augmented Forward Signal (AFS)
- AD1 Volume B LunaNet Signal-In-Space Recommended Standard (LSIS) Point-to-Point Signals
- AD2 LunaNet Measurement Schema and Parameters
- AD3 LunaNet Detailed Message Definition Document
- AD4 LunaNet Location Services for Users (not LunaNet 1.0)
- AD5 Lunar Reference System and LunaNet Reference Time System Standard
- AD6 LunaNet Data Services Document
- AD7 LunaNet LunaSAR Definition Document (not LunaNet 1.0)
- AD8 LunaNet Interoperability Security Specifications

LNIS v5

### LunaNet Interoperability Specification Document

Version 5

APPROVED

LunaNet Signal-In-Space Recommended Standard - Augmented Forward Signal (LSIS - AFS)  
VOLUME A

Version 1

*Noted as Applicable Document 1 [AD1 Vol-A] in LNIS V5*

Augmented Forward Signal is the broadcast service that offers PNT.

## Status

- LNIS Draft Version 5 and Applicable Document-1 Volume A, LunaNet Signal-In-Space Recommended Standard - Augmented Forward Signal\*
  - Dispositioned >500 public comments from space agencies, industry, and organizations;
  - Documents focus on agreed-upon near-term needs for required services, termed LunaNet 1.0;
  - Matures broadcast Augmented Forward Signal (AFS) definition;
  - Identifies select Point-to-Point and Direct With Earth signals;
  - Includes Data Services and a matured Service Access;
  - Consistency with document that defines user side of interface.
- Publication Feb 2025.
- Future LNIS update to complete LunaNet 1.0 specification to cover near term needs.



South Pole Region  
Service Volume



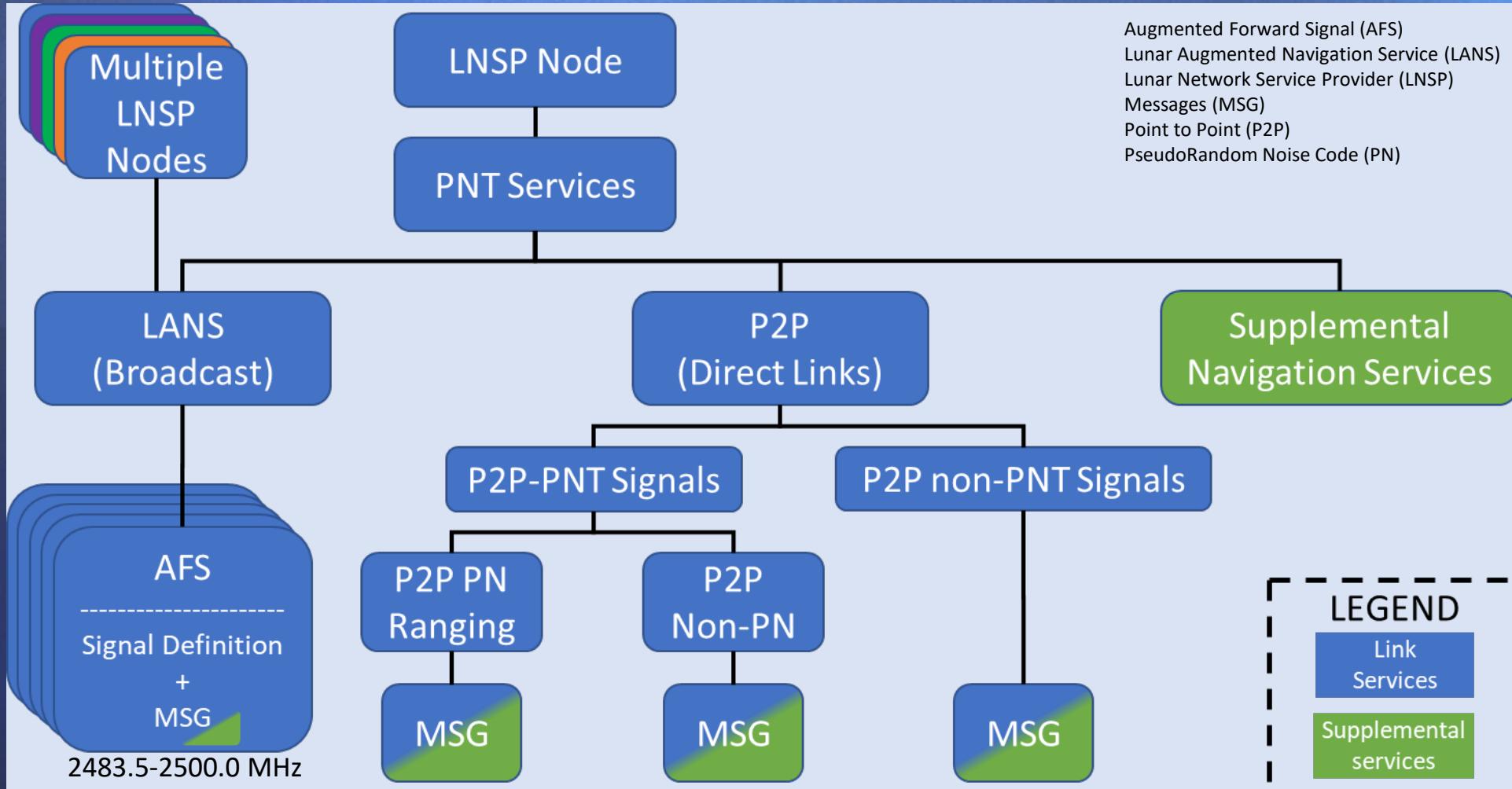
**LNIS version 5 and LSIS-AFS version 1 are available online.**

[https://www.nasa.gov/directorates/somd/space-communications-navigation-program/lunonet-interoperability-specification/#\\_blank](https://www.nasa.gov/directorates/somd/space-communications-navigation-program/lunonet-interoperability-specification/#_blank)

\* Technical paper and presentation available in ION ITM 2025 proceedings:  
<https://www.ion.org/itm/abstracts.cfm?paperID=15014>

# LunaNet Framework PNT Services

1449 1662 32 742



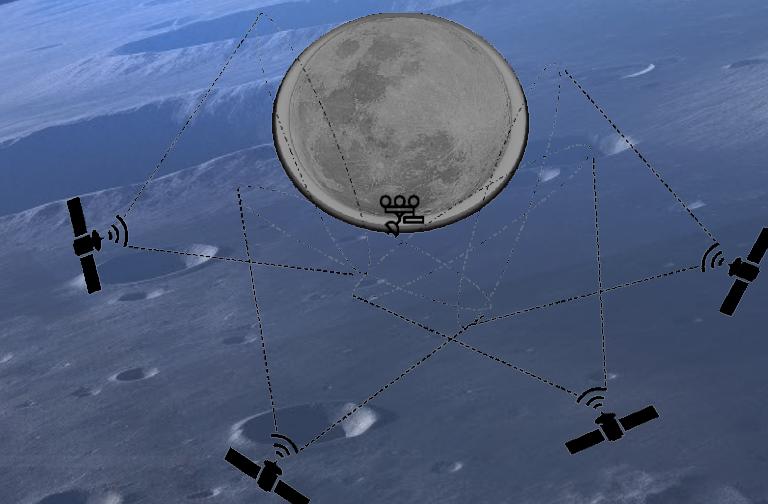
PNT Services rely on definition, adoption, and maintenance of common lunar geodetic reference and time systems.

## LunaNet PNT services:

1. Proximity:
  - a. Point-to-Point navigation services (direct link between the user and the provider); PNT-over-Comm
  - b. Lunar Augmented Navigation Service (LANS)
2. Direct With Earth
3. LunaNet Interoperability Spec responsible for defining signal designs, Signal in Space Error, messages for interoperable services.
4. Reliant on definition and maintenance of lunar reference geodetic and time systems.

## LANS characteristics:

- A lunar analog to terrestrial GPS/GNSS with associated benefits from broadcast signals and messages.
- The concept is to achieve maximum reuse of GNSS techniques and technologies.
- Defines a Lunar Service Volume (LSV) that extends beyond the local lunar surface region.
- This proximity service is provided from multiple providers nodes to multiple users at the same time.



# Interoperability is Critical to LANS

1449 1448 32 742

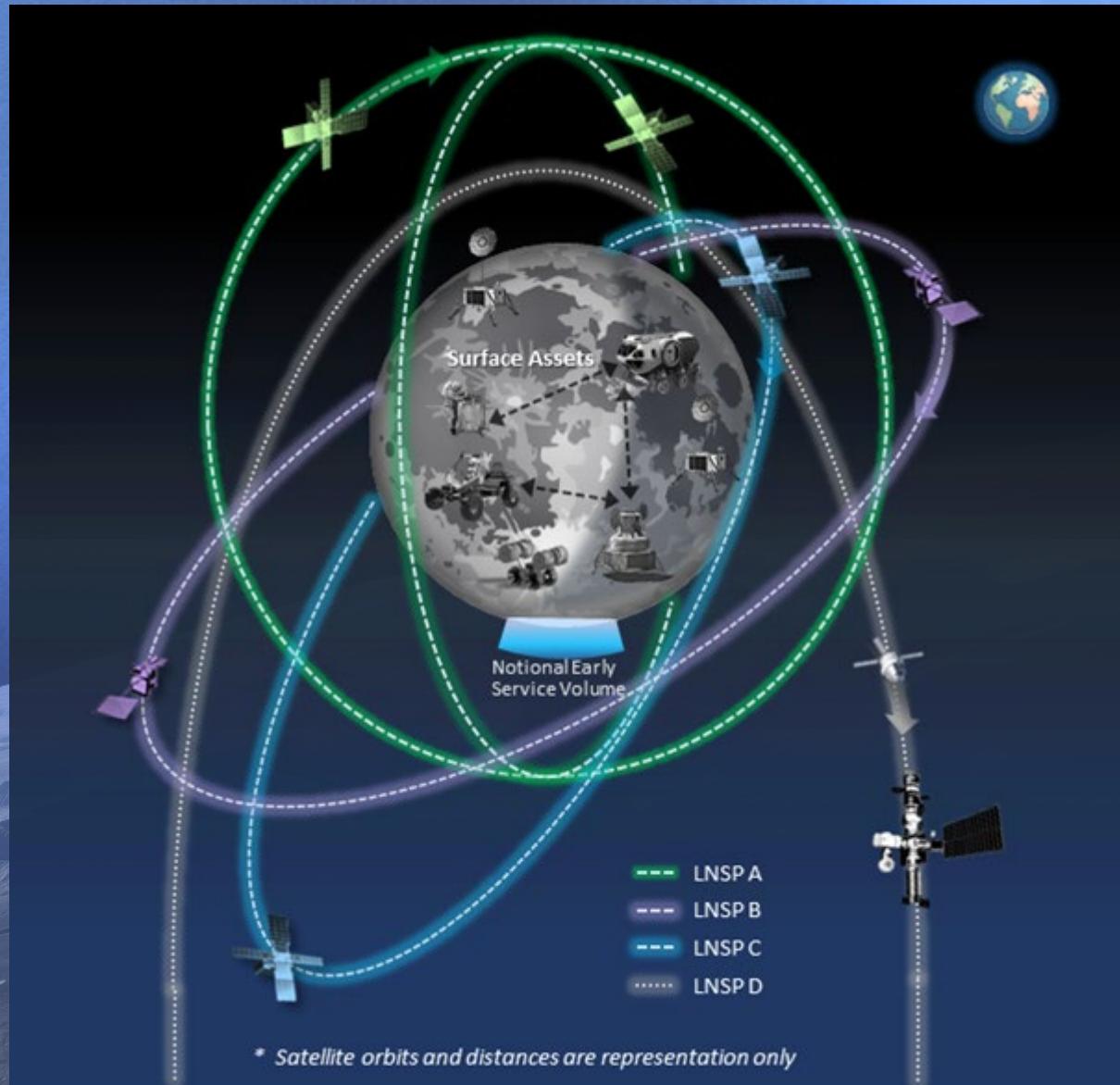


Current concept is to combine different LunaNet Service Provider (LNSP) space vehicles to create a constellation of AFS broadcasters for LANS.

- Interoperability is critical to achieve this.

**LANS Interoperability**<sup>1</sup>: each service provider that claims to be LunaNet compliant (becoming a LunaNet Service Provider, LNSP) for the LANS service, must:

- Comply with a common signal and message structure (Augmented Forward Signal, AFS).
- Comply with the Signal In Space Error requirements.
- Assure compliance with the Power at the Surface requirement.



<sup>1</sup> ICG SSV booklet: "(interoperability is defined as) the ability of global and regional navigation satellite systems, and augmentations and the services they provide, to be used together to provide better capabilities at the user level than would be achieved by relying solely on the open signals of one system"

# AFS Parameters (per AD-1 Vol A)

Carrier Center Frequency → 2492.028 MHz; Frequency Band → 2483.5 MHz to 2500.0 MHz; Polarization → RHCP

Two channels:

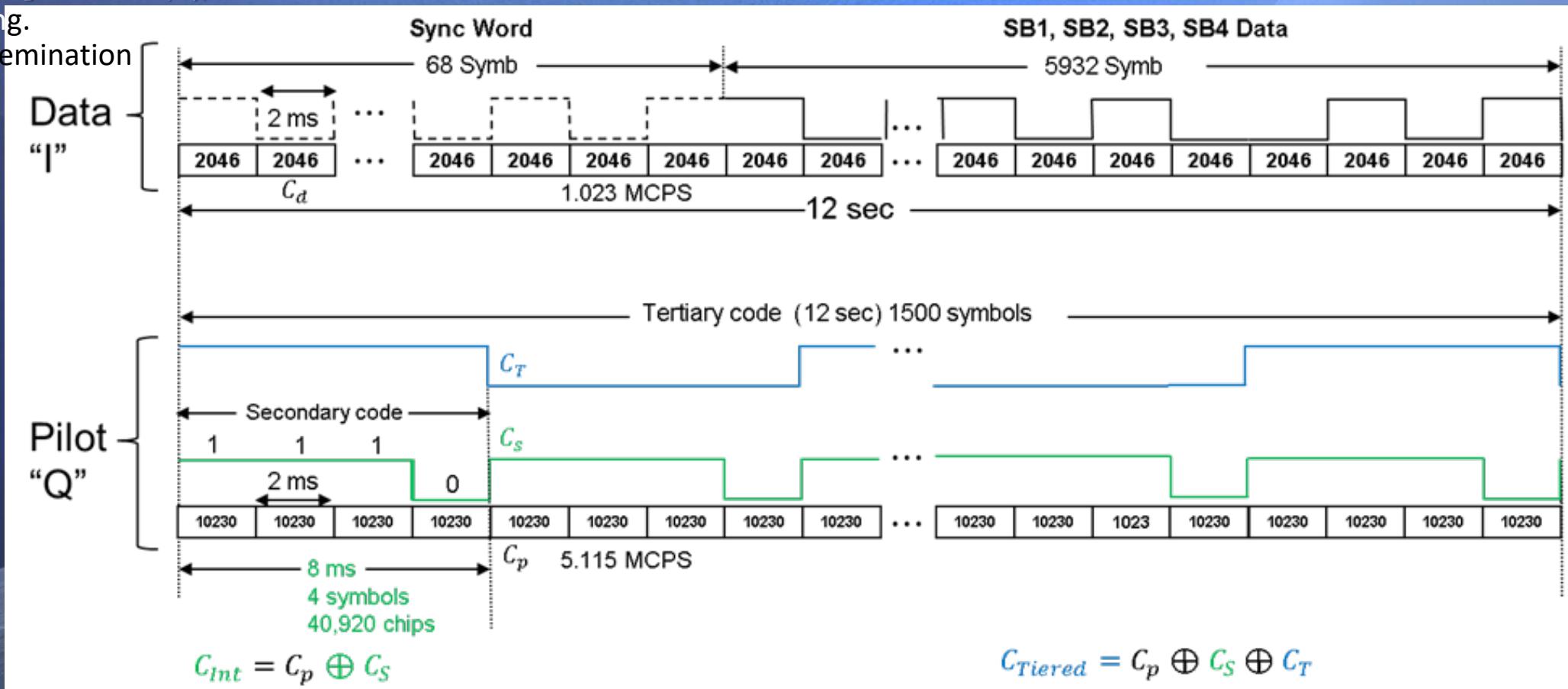
1) **Channel I [Data]** → BPSK(1), with PN code rate at 1.023 MHz

- a. Modulated with data symbols at 500 sps, supports frequent navigation data updates & other LunaNet data transmission needs;
- b. Frame synchronization pattern.
- c. SB1 includes Time of Interval (12 sec), Frame Identifier (FID), allowing future flexibility of data formatting

2) **Channel Q [Pilot]** → BPSK(5), with PN code rate at 5.115 MHz

- a. Precision tracking.

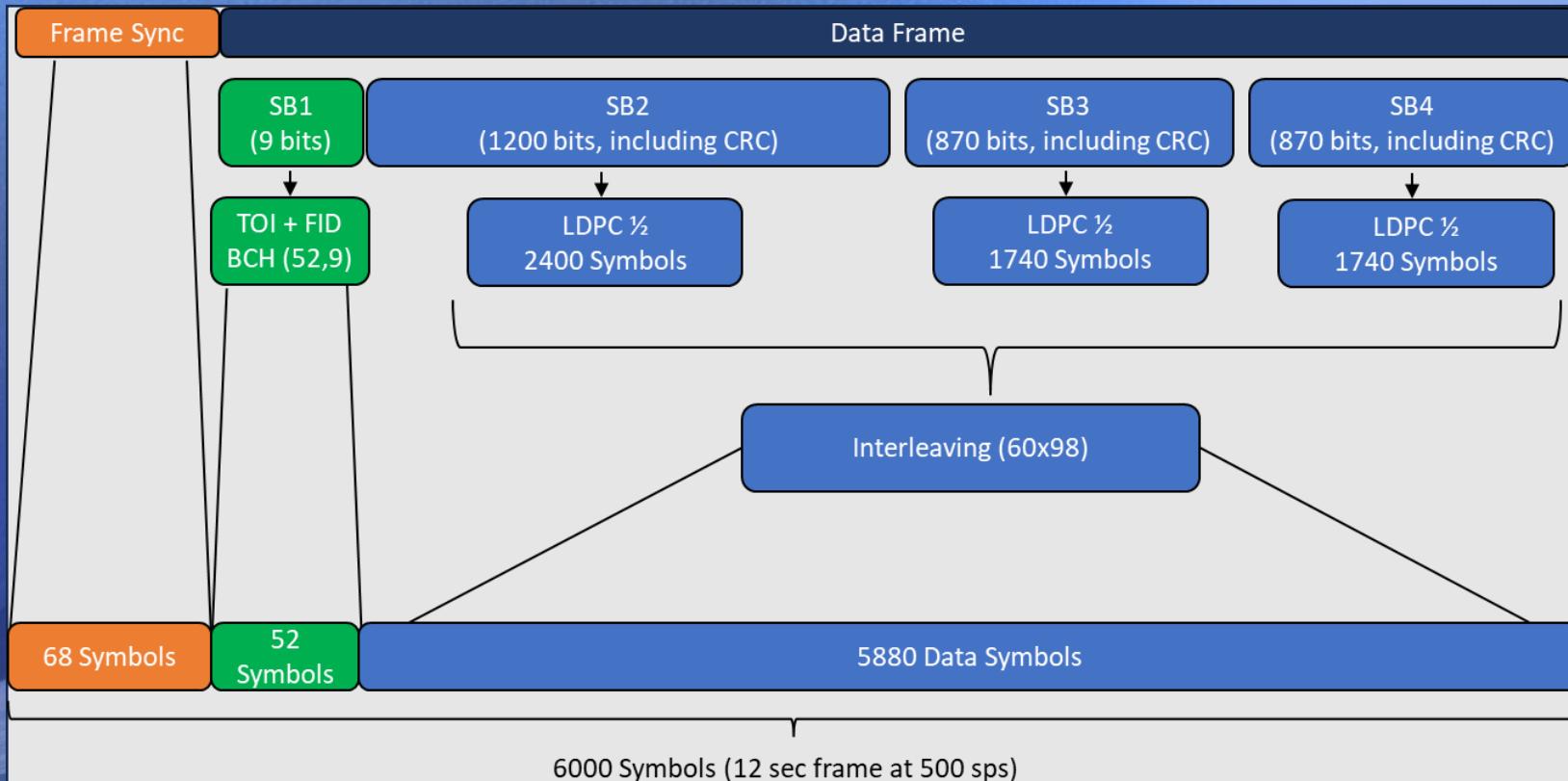
- b. Rapid Time Dissemination



The AFS Data channel leveraged the L1C design with some significant differences:

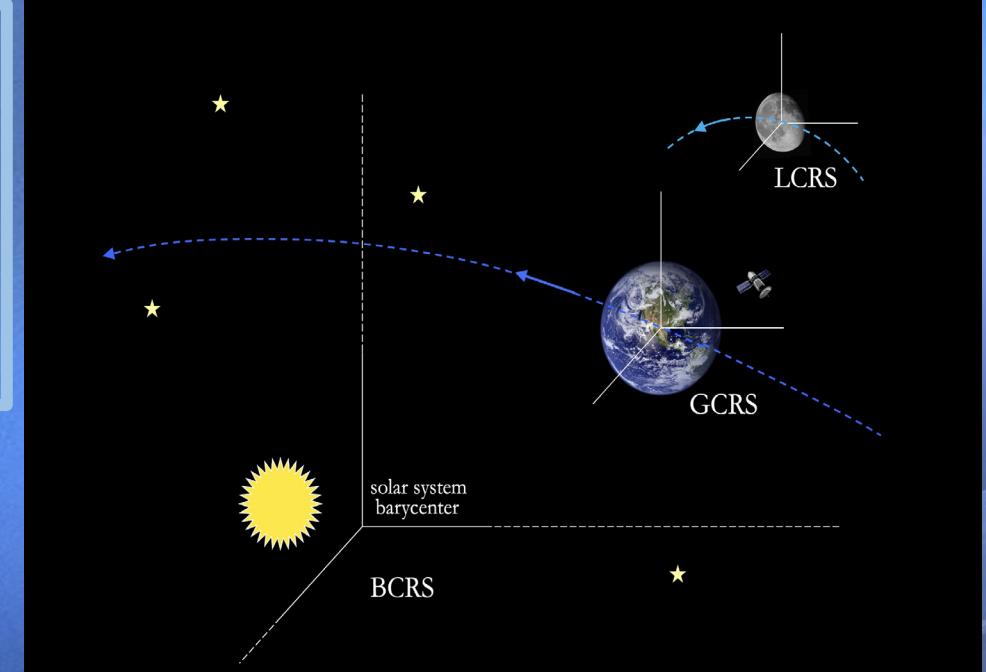
- BPSK(1) Modulation instead of BOC(1,1);
- 250 bits/sec instead of 50 bits/sec;
- 50 % Power is in the data channel instead of 25% as L1C;
- Sync word for low complexity receivers that do not acquire and track the pilot channel;
- LDPC decoding as described in the 5G NR standard.

## Data Channel Frame Structure with Frame ID = 0



**LunaNet Interoperability Specification AD-5:  
will define the interoperable parameters for  
reference systems and time that LunaNet-  
compliant services must meet.**

LunaNet PNT relies on the international standards organizations, such as the International Astronomical Union (IAU), International Association of Geodesy (IAG), Bureau International des Poids et Mesures (BIPM), and International Telecommunications Union (ITU), to identify definitions of these critical underpinnings through international recognition and consensus.



*More on this in Session 3 of this Workshop.*

**PNT Services rely on definition, adoption, and maintenance of common lunar geodetic and time systems, and transforms to other frames and UTC.**

- The Interagency Operations Advisory Group initiated a Committee to Study LunaNet Governance.
- Recognizing that near-term coordination is needed, the three agencies participating in LunaNet will form the Coordinated LunaNet Administration Partners to handle items such as:
  - Allocation of specific identifiers to LNSP nodes
  - Reference orbits
  - Parameter/signal monitoring and validation

# LunaNet Orbital PNT Service Providers



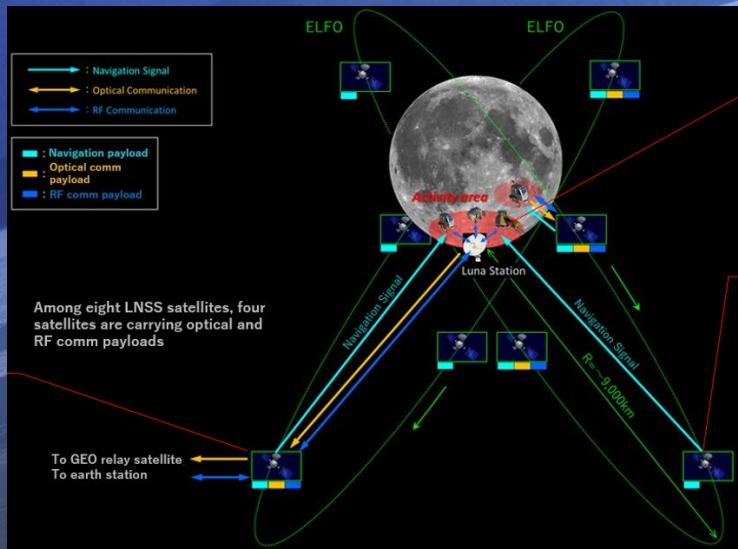
ESA Moonlight  
LCNS  
(2028～)

Contractor:  
Telespazio



Japan LNSS  
(2028/2029～)

ArkEdge Space  
was recently  
selected  
※PNT only



NASA LCRNS  
(2026～)

Contractor:  
Intuitive  
Machines



**LCNS:**  
Lunar Communications and  
Navigation Services  
**LCRNS:**  
Lunar Communications Relay  
and Navigation Systems  
**LNSS:**  
Lunar Navigation Satellite System

- LunaNet definition established currently via tri-lateral working groups to develop interoperability specifications that address communications, PNT, data services, security, and the foundational reference systems for these services in the lunar environment.
- LunaNet leverages international standards where applicable.
- The Augmented Forward Signal provides a broadcast signal for PNT, similar to terrestrial GNSS concept.
- Point-to-Point signals offer additional PNT capability, including delivery of messages for supplemental navigation/time products.
- NASA, ESA, and Japan instantiations of LunaNet systems are underway.

Questions?