



# LunaNet, Interoperability, And NASA's Lunar Relay PNT Services

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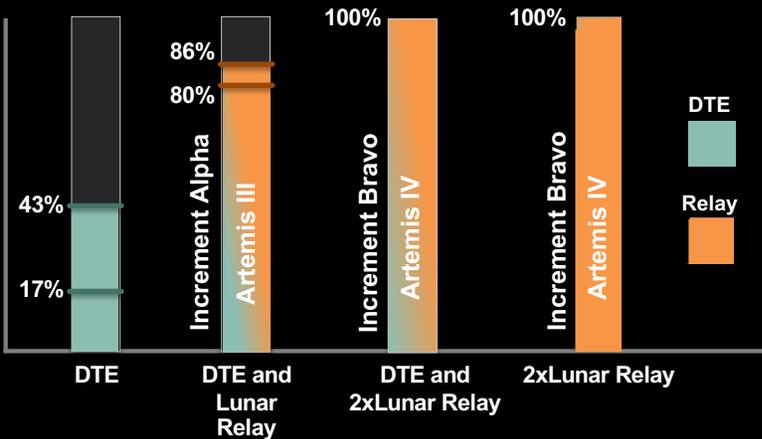
Presenter:  
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# The Need for Lunar Relays



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**Yearly Average Communications and PNT Coverage for Worst/Best Case Lunar South Pole Landing Sites**



DTE and a **single** lunar relay provides dramatic improvement on landing site availability and safety.  
**Two relays** provide 100% coverage.

- ❖ Coverage based on 10-year line-of-sight simulation.
- ❖ DTE coverage is using center of Earth.
- ❖ Lower bound (worst case) coverage assumes HLS lands at Spudis Ridge Peak and upper bound coverage (best case) assumes landing at Mount Malapert Peak.

DTE = Direct to Earth

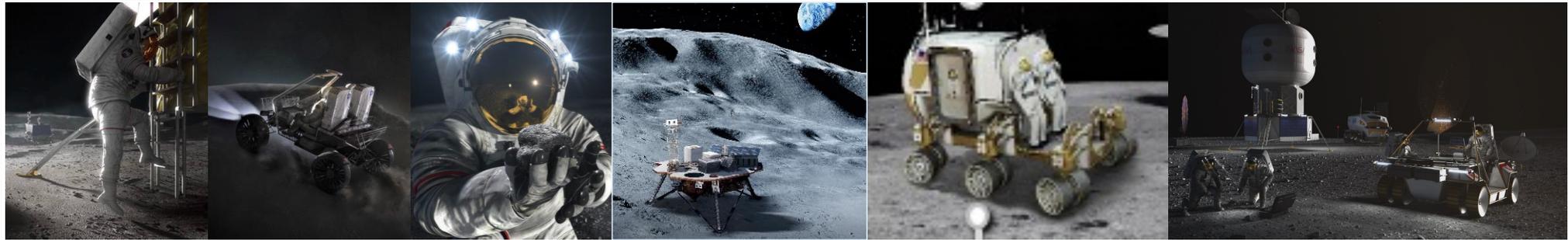


Without Lunar Relays: **DTE coverage, reduced geometry, and lighting conditions, severely constrain landing site availability and operational safety!**

# User Drivers



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- Global, safe navigation
- Highly dynamic environment (e.g. descent, ascent)
- Situational Awareness
- Efficient operations due to EVA time constraints and multiple mission objectives
  - Limited survivability resources
  - Apollo-type navigation (orienteering) requires stop-time
  - Contingency walk-back scenarios
- Telerobotic operations, e.g. LTV surface prep for crew
- Real time localization on a map
- Accurate science





# Lunar Systems Relationships



## LunaNet

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

**Lunar Comm. Relay and Navigation System (LCRNS)**

NASA's instantiation of LunaNet Lunar Relay Services— a LunaNet Service Provider (LNSP)

Currently scoped for Initial Operating Capability

**Moonlight Lunar Communication and Navigation System (LCNS)**

ESA's instantiation of Lunar Relay Services

**Lunar Navigation Satellite System (LNSS)**

Japan's instantiation of Lunar Relay Services

**Ground Stations for Lunar Missions**

e.g. NASA's Lunar Exploration Ground Segment

**Others**

e.g. other orbiting systems, surface comm and/or PNT systems (future), ground systems, users

**Lunar Reference System(s) Components (includes Time)**

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

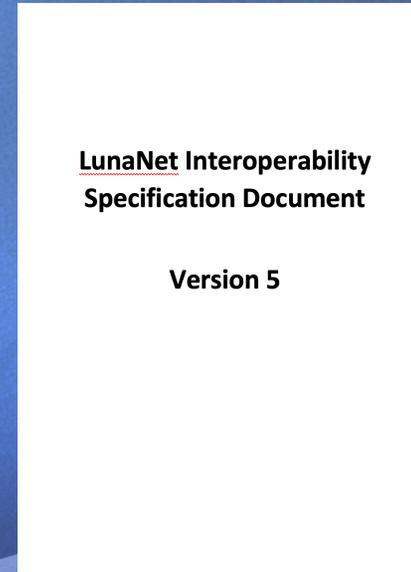
# LunaNet Interoperability Specification



## 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



AD1 Vol A, LSIS-AFS v1



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



# Interoperability is Critical to LANS



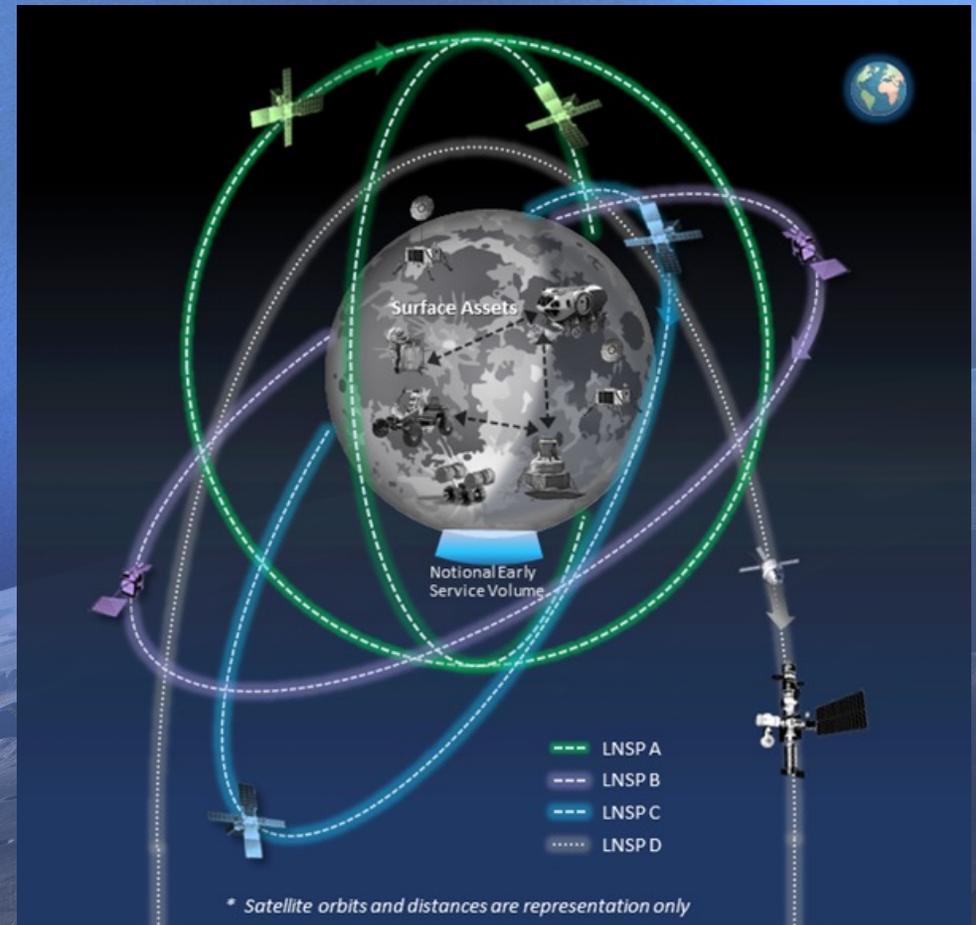
Current concept is to combine different LunaNet Service Provider (LNSP) space vehicles to create a constellation of AFS broadcasters for LANS.

➤ 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"

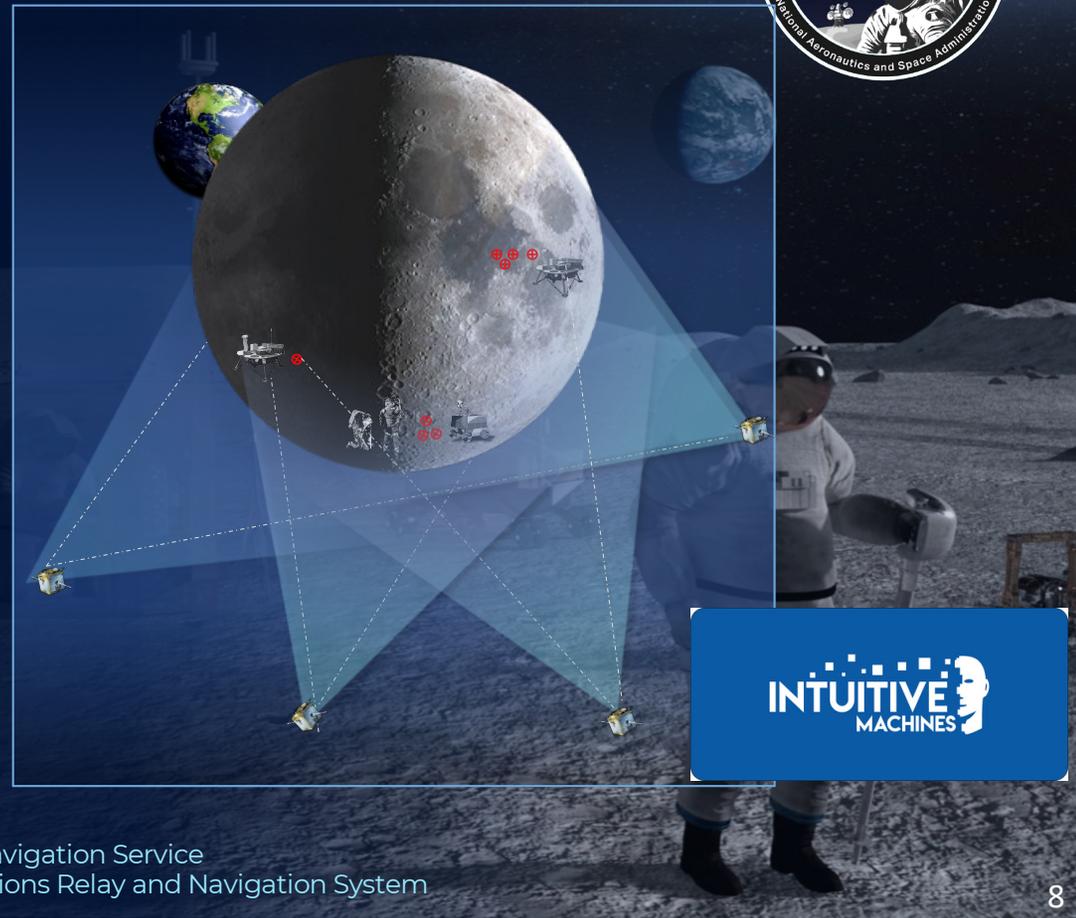


# Initial LANS\* Capability for NASA's LCRNS^

- Initial Operating Capability is expected to consist of three distinct phases over a period of approx. 5 years:
  - Phase Alpha, with a minimum of one Augmented Forward Signal (AFS) expected to broadcast over the South Pole region.
  - Phase Bravo, with a minimum of two AFS expected over the same South Pole region.
  - Phase Charlie, with an expected minimum of four AFS in view in an expanded service volume (for a limited portion of each Earth day). Additionally meeting a requirement for Geometric Dilution of Precision (GDOP).
- The LCRNS AFS is expected to comply with the LunaNet Interoperability Specification.
- LCRNS orbit(s) are defined by the service provider and relays are expected to meet the Signal-in-Space-Error in the LCRNS SRD.
- Service delivery is reliant on defined lunar geodetic system and lunar time.

\*LANS = Lunar Augmented Navigation Service

^LCRNS = Lunar Communications Relay and Navigation System



# LCRNS Interoperable PNT Services



## ➤ AFS Interoperability

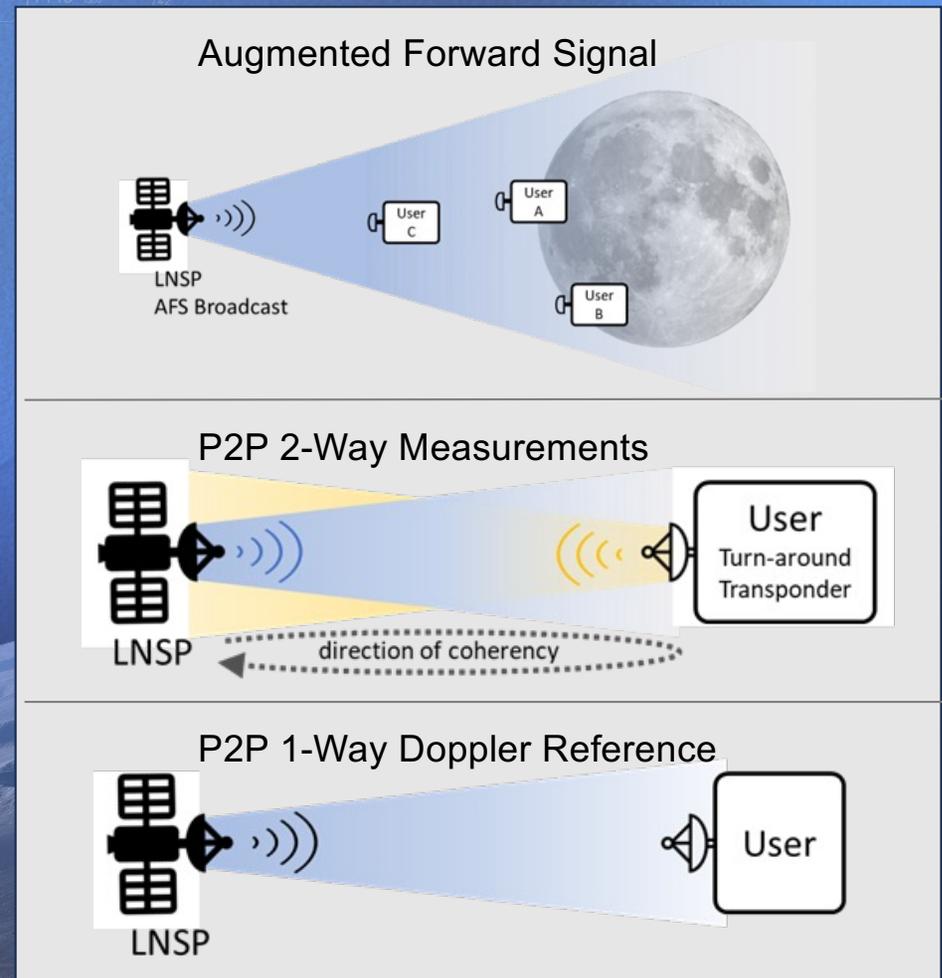
- A. Draft Specifications per LNIS AD1 Vol-A, LunaNet Signal In Space Recommended Standard for AFS
- B. Modulations, spreading codes, data encoding, power levels, etc.
- C. Performance requirements per LCRNS SRD

## ➤ P2P PNT Services

- A. 2-Way Measurements, including Range and Doppler
- B. 1-Way Doppler Reference Signals

## ➤ Information over Messages

- A. Constellation almanac
- B. Precise ephemeris
- C. P2P Observables
- D. Coordinate and Time Transformations



# Concluding Summary

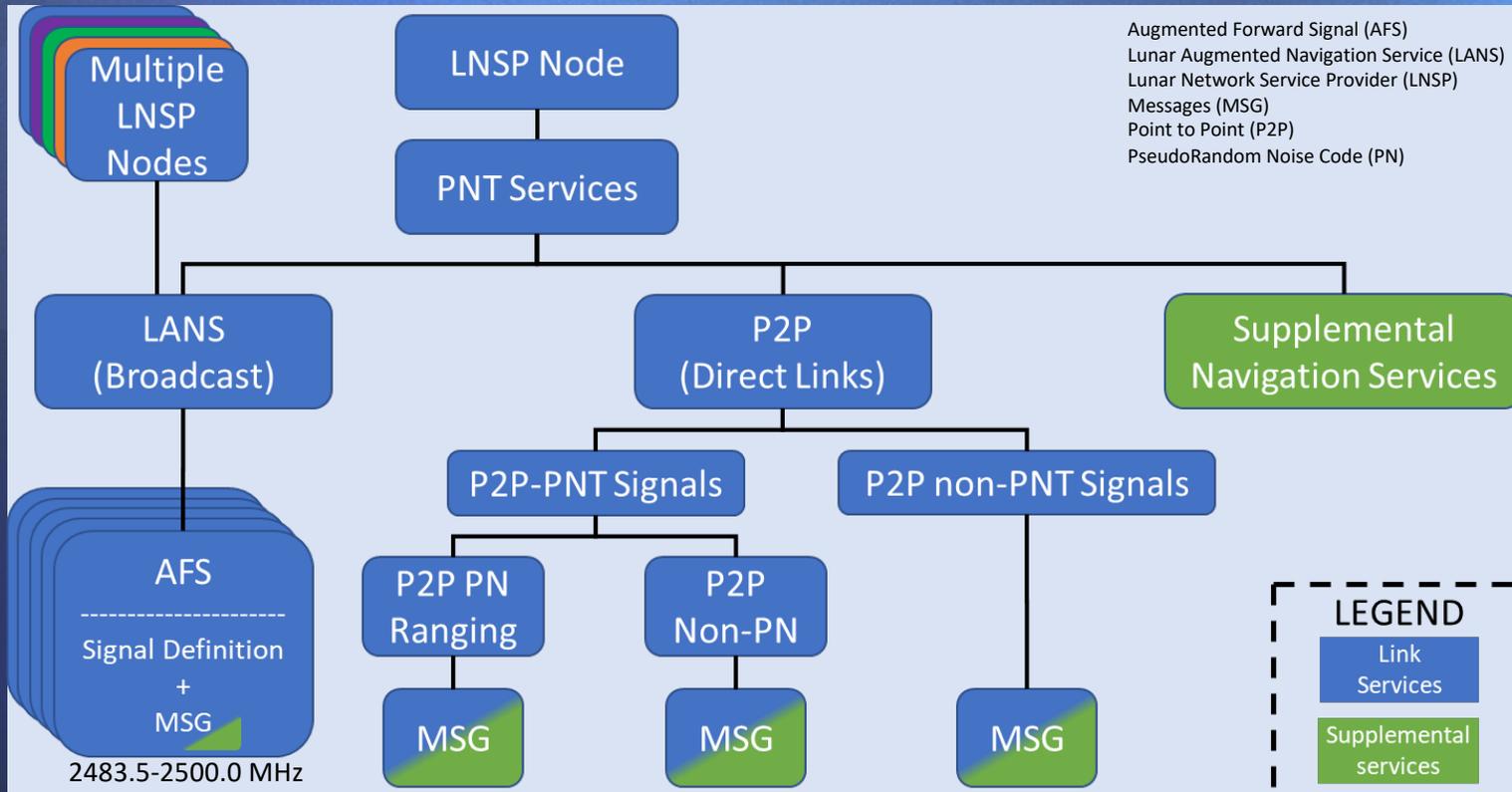
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- An identified need for lunar relays and in-situ radionavigation PNT exists for the lunar user community.
- LunaNet definition established currently via tri-lateral working groups to develop interoperability specifications that address communications, 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 has contracted with Intuitive Machines to deliver LunaNet-compliant PNT services.



# LunaNet Framework PNT Services



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