

Space Communications & Navigation

**Lunar Communications & Navigation
Interoperability Specification**

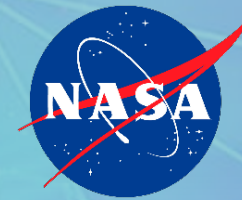
Version 2

April 27, 2022

Agenda

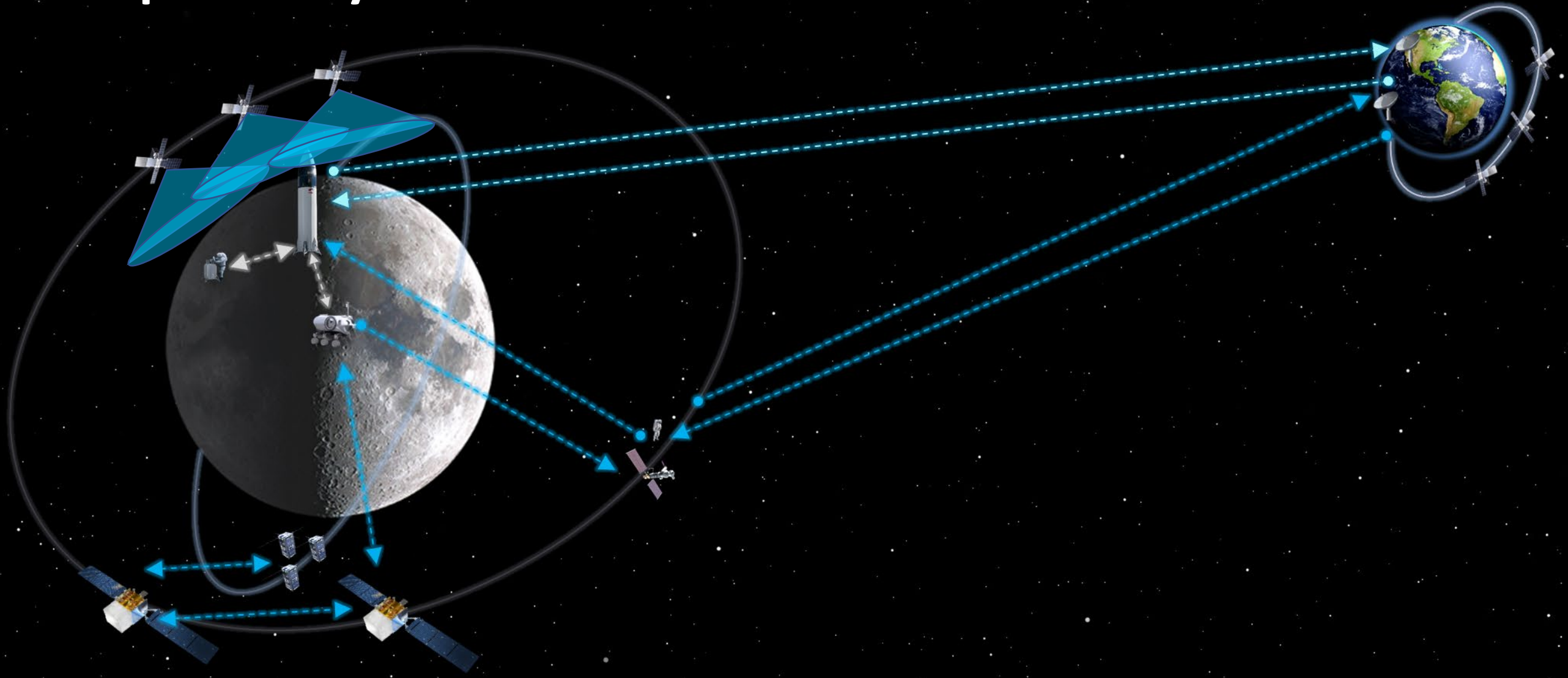
Topic	Presenter
Introduction	Andrew Petro, NASA HQ SCaN
LunaNet Interoperability Update https://go.nasa.gov/3BQrCOk	David Israel, NASA Goddard Architect Cheryl Gramling, NASA Goddard Navigation Lead
Discussion	All

If you have questions or comments during the session, please place them in the chat box.



Introduction

LunaNet Overview and Interoperability Document



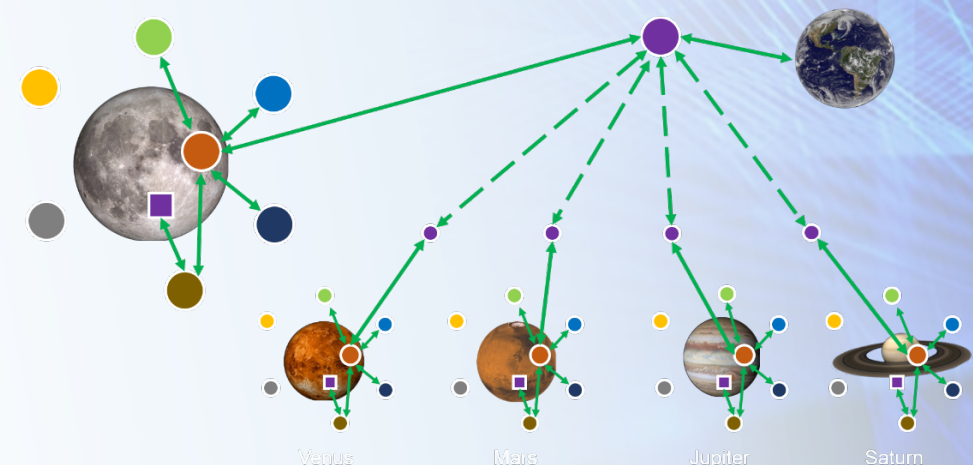
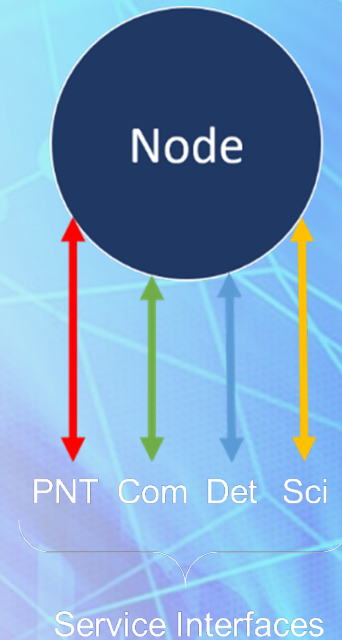
LunaNet



- A flexible scalable architecture for providing communications and navigation services to all lunar missions
- Disaggregated approach allows for phased implementation of infrastructure as driven by user needs and technology developments
- Architecture implementation comprised of NASA, International, and Commercial interoperable lunar surface, lunar orbiting, and earth-based elements
- Incorporates in-situ capabilities to detect events and distribute situational alerts
- Is fully compatible with future deployments at Mars or any other destination

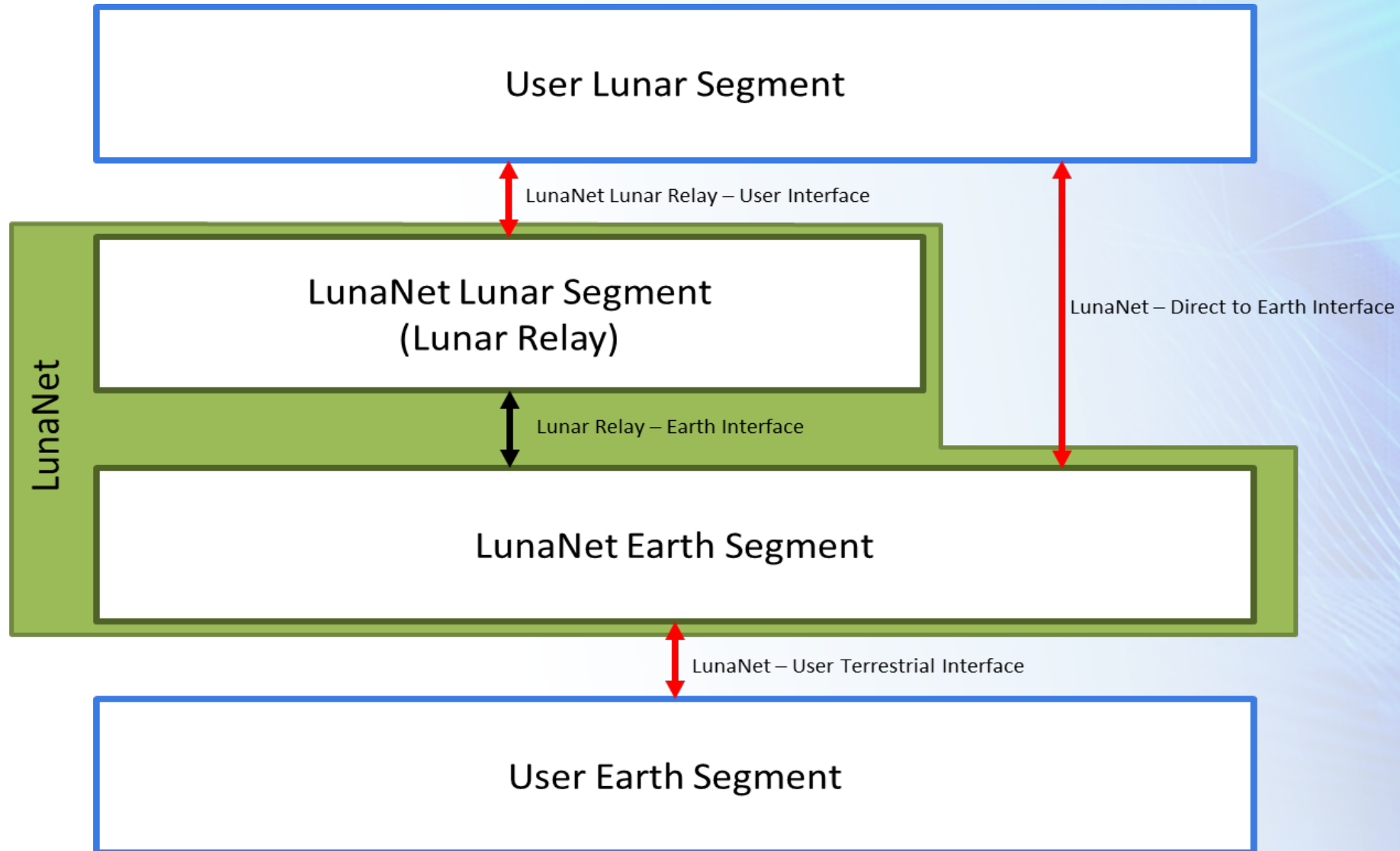
LunaNet Service Types

1. **Communications Services (Com):** Data transfer services capable of moving addressable and routable data units between nodes in a single link or over a multi-node, end-to-end path via communications or networking services.
2. **Position, Navigation, and Timing Services (PNT):** Services for position and velocity determination, and time synchronization and dissemination. This includes search and rescue location services.
3. **Detection and Information Services (Det):** Services providing detection of events in order to generate timely alerts for human and asset safety and protection. These services publish other beneficial information to users as well.
4. **Science (Sci):** Services that use the RF and/or optical capabilities of the node as a science instrument or part of an instrument.

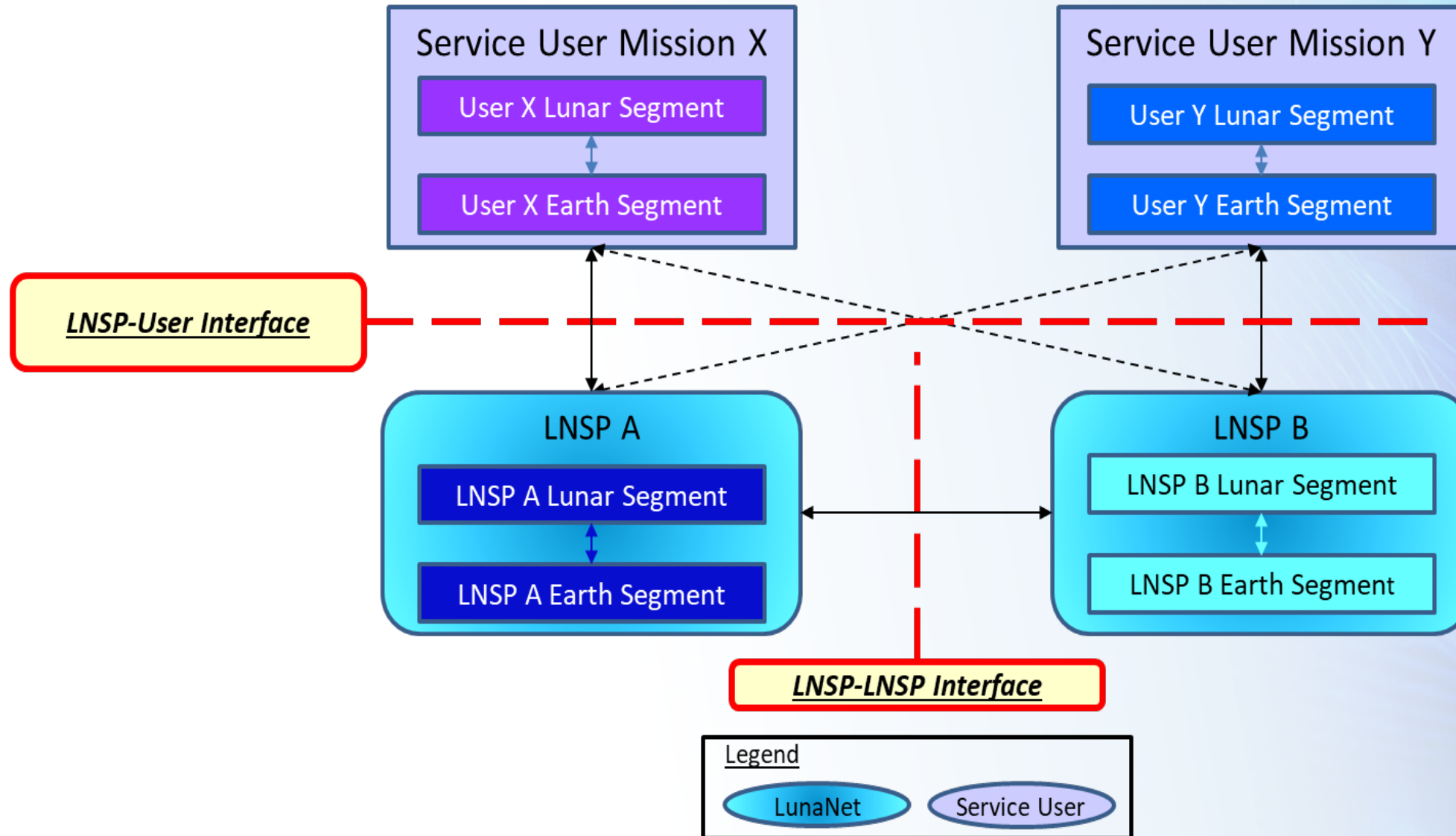


Just as the Internet and GPS have transformed our lives on Earth, LunaNet will transform lunar science and exploration.

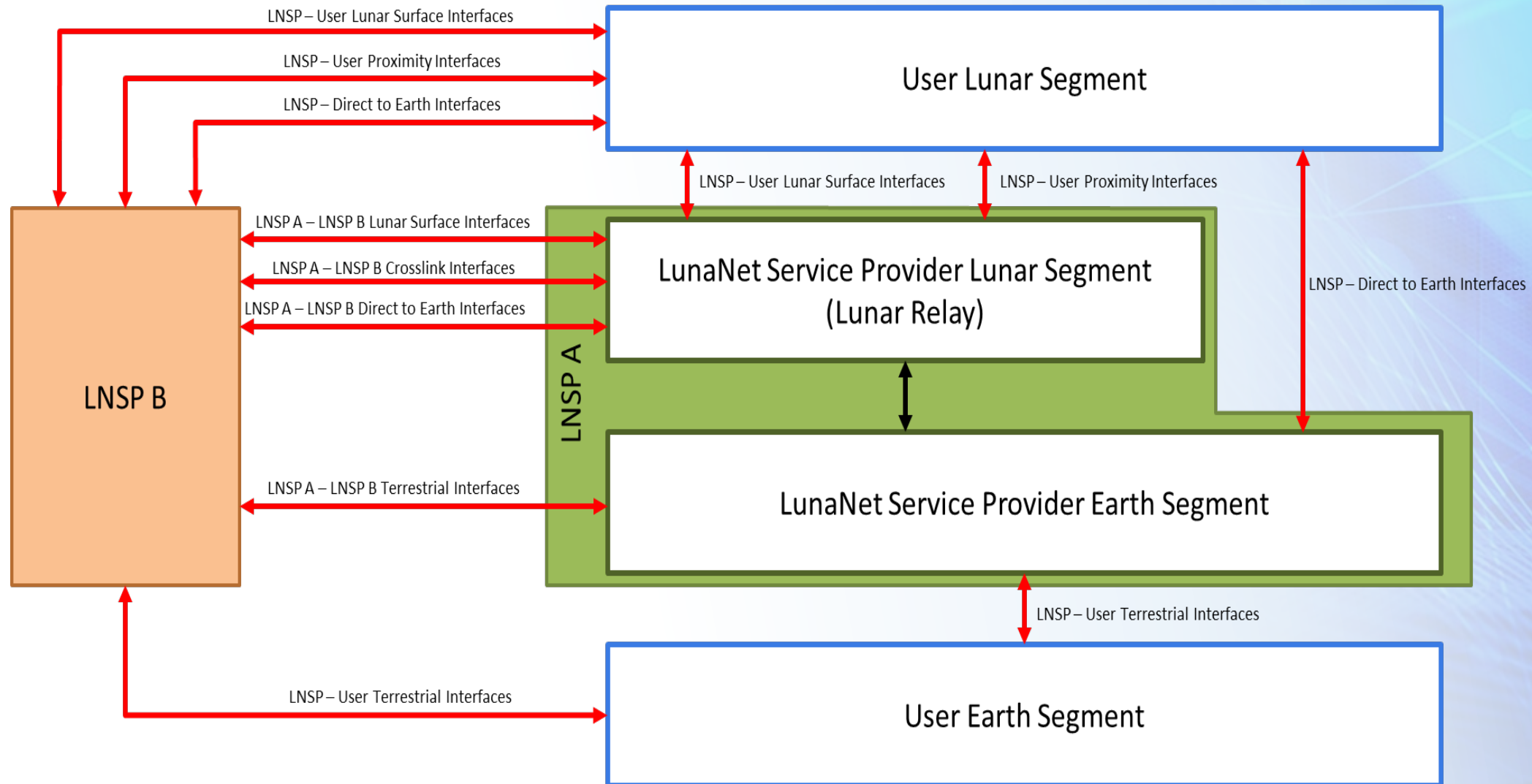
LunaNet Segments



LunaNet Standard Services and Interfaces



LunaNet Service Provider Interfaces



Significant LIS Updates

- Version 2 was released on March 17, 2022 (<https://go.nasa.gov/3BQrCOk>)
- Updates produced jointly by NASA and ESA
- Clarification on document scope
- Use of 2483.5 – 2500 MHz for Lunar Augmented Navigation Service (LANS)
- Addition of Unified Space Data Link Protocol (USLP)
- Updates to proximity link coding and modulations
- Additional PNT content
- Identification of initial set of Message Titles

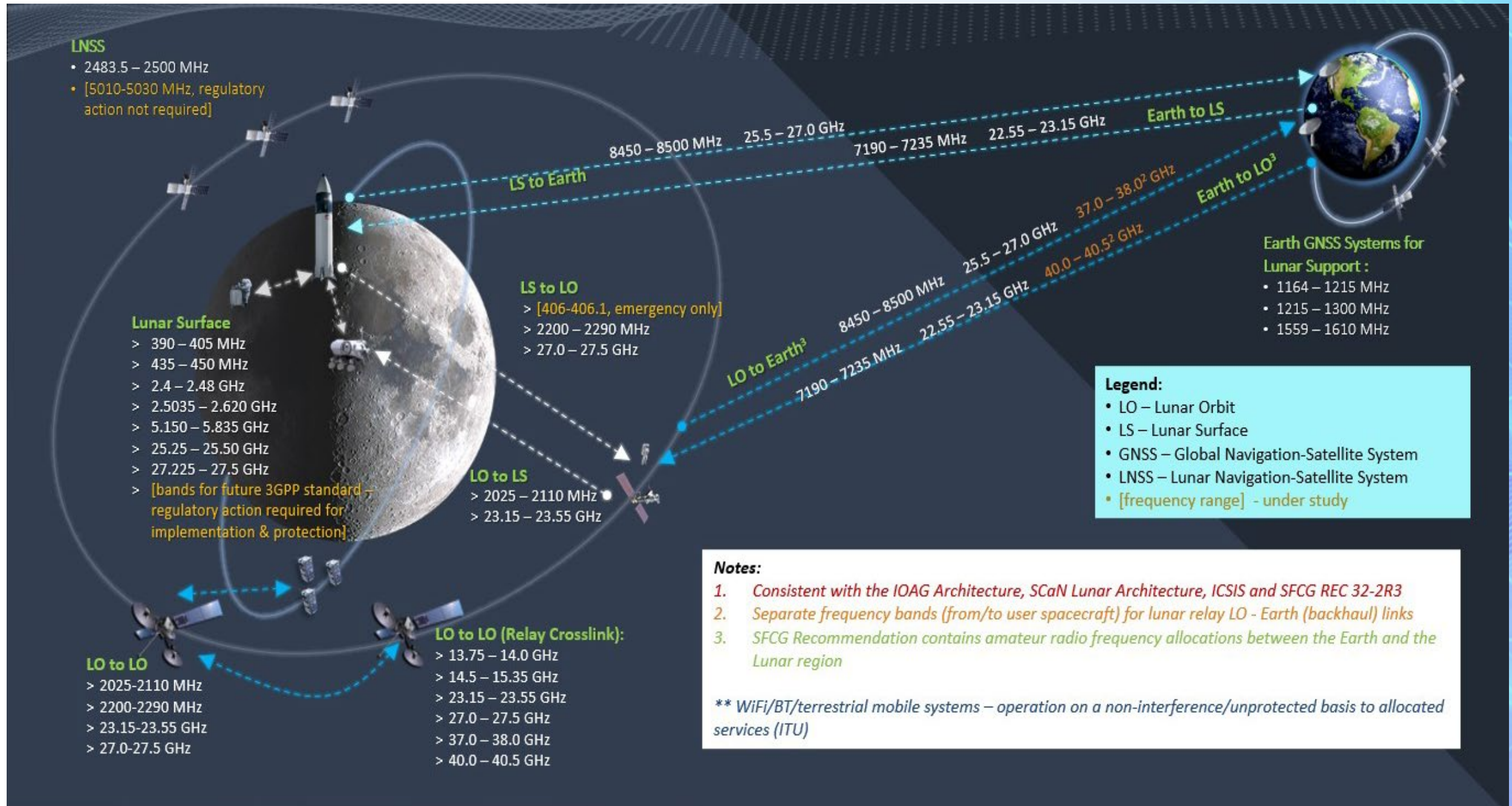
LunaNet Interoperability Specification

Document Purpose

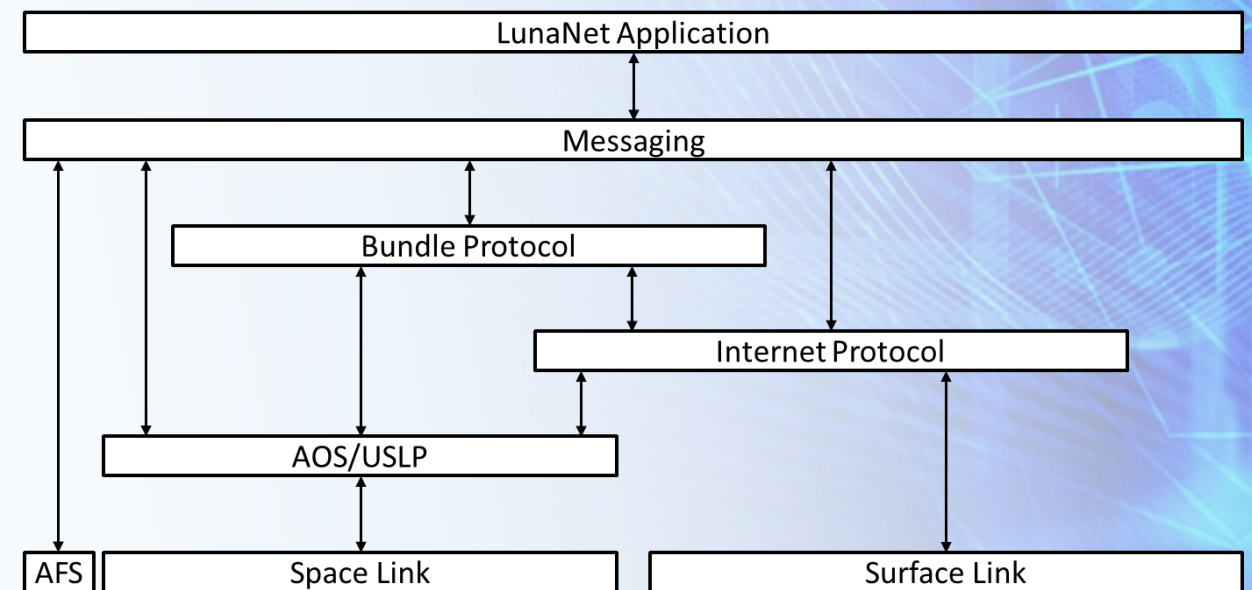
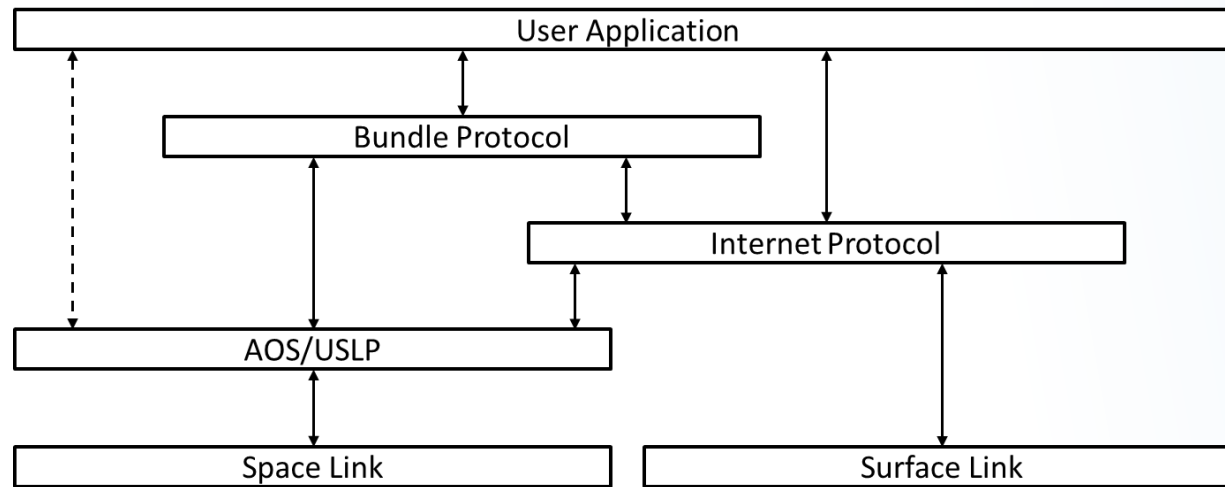
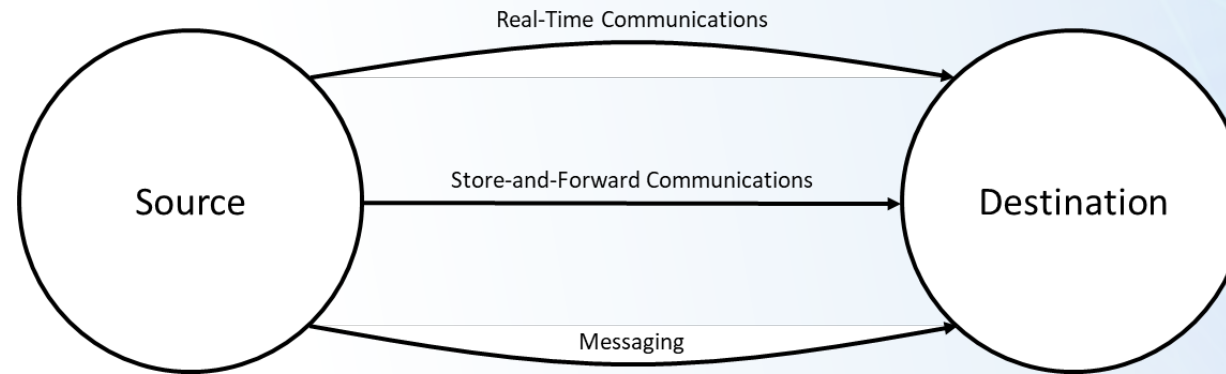
Define the standard services and interfaces for LunaNet service providers to administer interoperable services to meet the needs of missions operating in the lunar vicinity.

- Not intended to replace either the International Communication System Interoperability Standards (ICSIS) or the Interagency Operations Advisory Group's (IOAG) Lunar Communications Architecture Documents.
- Provides the minimum set of standard services and interfaces that will be available to lunar users, such that users may design their systems with the expectation of available providers.
- Any individual provider is not required to offer all services and interfaces in this document, but the aggregation of providers will have the interfaces and services described.
- Providers may offer services and interfaces beyond what is described in this document.
 - Those services and interfaces will likely not be interoperable between service providers, thereby limiting the service options for a user

LunaNet Interoperability Frequency Plan



LunaNet Communications Services



LunaNet Proximity Links (1/4)

Interface Name	Interface Type	Targeted Frequency Range	Modulation	Coding ¹ , slicing (Code rate and codeword length)	Frame Size, AOS, USLP ²	Applicable Documents
		Note: exact center frequency to be determined based on user requirements, conops, and are subject to coordination.		Slicing is recommended (when approved, frame size can be other than shown in frame column)	AOS and USLP to be supported	CCSDS 732.1-B-2 for USLP
PFS1a	Proximity Forward S-Band Link	2025-2110 MHz 1 Msps <Rs< 2 Msps Maximum band=5 MHz per user	Filtered BPSK/BPSK + NRZ-L	LDPC code rates 1/2 (4096 octets plus 64-bit ASM) LDPC code rate 4/5 (2560 octets plus 64-bit ASM) LDPC code rate 7/8 (1020 octets plus 32-bit ASM) uncoded (2048 octets plus a 32-bit ASM),	AOS, frame size 2048 octets for LDPC rate 1/2, and rate 4/5, or AOS, frame size 892 octets (for LDPC rate 7/8 USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PFS1b	Proximity Forward S-band Link	2025-2110 MHz 1 ksps<Rs<1 Msps Maximum band=5 MHz per user	Filtered BPSK/BPSK + NRZ-L	LDPC rate 1/2 (256 octets plus 64-bit ASM)	AOS, frame size 128 octets USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PFS1c	Proximity Forward S-band Link	2025-2110 MHz 48 ksps <Rs<1.024 Msps Maximum band=5 MHz per user	PCM/PM/bi-phase-L, with PN ranging (for without PN see Appendix C)	LDPC rate 1/2 (256 octets plus 64-bit ASM) LDPC rate 2/3 (768 octets) (to be recommended) Conv. 1/2, k = 7 (to be recommended)	AOS, frame size 128 octets for rate 1/2 LDPC AOS, frame size 512 octets for rate 2/3 LDPC USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PFS1d	Proximity Forward S-band Link	2025-2110 MHz 0.5 ksps < Rs < 48 ksps Maximum band=5 MHz per user	PCM/PSK/PM +NRZ-L, with PN ranging Sinewave subcarrier frequency=max (4Rs, 8kHz)	LDPC rate 1/2 (256 octets plus 64-bit ASM)	AOS, frame size 128 octets USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PFS1e	Proximity Forward S-band Link	2025-2110 MHz 1 Msps <Rs<5 Msps Maximum band=5 MHz	GMSK and Filtered OQPSK for high rates (to be recommended)	LDPC rate 1/2 (256 octets plus 64-bit ASM) LDPC rate 1/2 (1024 octets) (to be recommended) LDPC rate 2/3 (768 octets) (to be recommended) Conv. 1/2, k = 7 (to be recommended)	AOS, frame size 128 octets for rate 1/2 256 octets AOS, frame size 512 octets for rate 1/2 1024 octets and 2/3 768 octets USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3

LunaNet Proximity Links (2/4)

Interface Name	Interface Type	Targeted Frequency Range	Modulation	Coding ¹ , slicing (Code rate and codeword length)	Frame Size, AOS, USLP ²	Applicable Documents
		Note: exact center frequency to be determined based on user requirements, conops, and are subject to coordination.		Slicing is recommended (when approved, frame size can be other than shown in frame column)	AOS and USLP to be supported	CCSDS 732.1-B-2 for USLP
PFS2	Proximity Forward S-band Link	2025-2110 MHz Data rates <300 ksps Maximum band=6.16 MHz per user	SS-BPSK CDMA (~3Mcps) or SS-UQPSK (Appendix C)	LDPC rate ½ (256 octets plus 64-bit ASM)	AOS, frame size 128 octets USLP	CCSDS 415.1-B-1 CCSDS 131.0-B-3
PFS5	Proximity Broadcast S-band Link for Comm/PNT	2483.5-2500 MHz (Fc: 2492.028 MHz) Data Rate 250 to < 1 ksps	AFS structure (Appendix C)	AFS Structure (Appendix C)	AFS structure (Appendix C)	LunaNet and User Signal Structure Definition Document [AD1]
PFS6	Proximity Forward S-band Link	2025-2110 MHz Data rates <300 ksps Maximum band=6.16 MHz per user	TBD	TBD	TBD	LunaNet and User Signal Structure Definition Document [AD1]
PRS1a	Proximity Return S-Band Link	2200-2290 MHz 1 Msps<Rs<2 Msps Maximum band=5 MHz	Filtered BPSK/BPSK + NRZ-L	LDPC code rates 1/2 (4096 octets plus 64-bit ASM) LDPC code rate 4/5 (2560 octets plus 64-bit ASM) LDPC code rate 7/8 (1020 octets plus 32-bit ASM) uncoded (2048 octets plus a 32-bit ASM),	AOS, frame size 2048 octets for LDPC rate ½, and rate 4/5, AOS, frame size 892 octets (for LDPC rate 7/8 USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PRS1b	Proximity Return S-Band Link	2200-2290 MHz 1 ksps<Rs<1 Msps Maximum band=5 MHz	Filtered BPSK/BPSK + NRZ-L	LDPC rate ½ (256 octets plus 64-bit ASM)	AOS, frame size 128 octets USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3

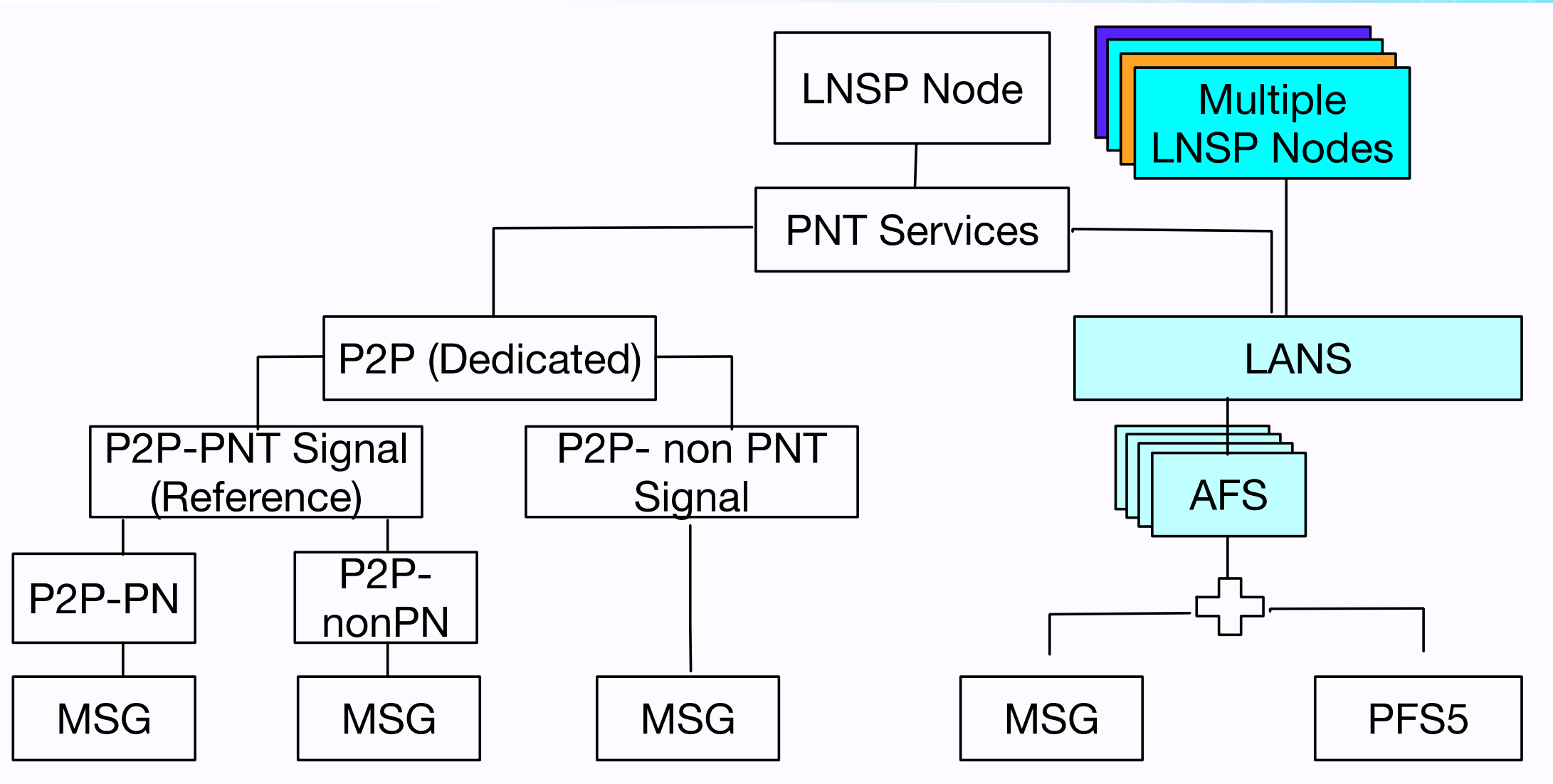
LunaNet Proximity Links (3/4)

Interface Name	Interface Type	Targeted Frequency Range	Modulation	Coding ¹ , slicing (Code rate and codeword length)	Frame Size, AOS, USLP ²	Applicable Documents
		Note: exact center frequency to be determined based on user requirements, conops, and are subject to coordination.		Slicing is recommended (when approved, frame size can be other than shown in frame column)	AOS and USLP to be supported	CCSDS 732.1-B-2 for USLP
PRS1c	Proximity Return S-Band Link	2200-2290 MHz 48 ksps<Rs<1.024 Msps Maximum band=5 MHz	PCM/PM/bi-phase-L	LDPC rate ½ (256 octets plus 64-bit ASM) LDPC rate 2/3 (768 octets) (to be recommended) Conv. ½, k = 7 (to be recommended)	AOS, frame size 128 octets for rate ½ LDPC AOS, frame size 512 octets for rate 2/3 LDPC USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3 CCSDS 211.0-B-6, CCSDS 211.1-B-4, CCSDS 211.2-B-3
PRS1d		2200-2290 MHz 0.5 ksps < Rs < 48 ksps Maximum band=5 MHz	PCM/PSK/PM +NRZ-L, with PN ranging Sinewave subcarrier frequency=max (4Rs, 8 kHz)	LDPC rate ½ (256 octets plus 64-bit ASM)	AOS, frame size 128 octets USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PRS1e		2200-2290 MHz 1 Msps<Rs<5 Msps Maximum band=5 MHz	GMSK and Filtered OQPSK for high rates (to be recommended)	LDPC rate ½ (256 octets plus 64-bit ASM) LDPC rate 1/2 (1024 octets) (to be recommended) LDPC rate 2/3 (768 octets) (to be recommended) Conv. ½, k = 7 (to be recommended)	AOS, frame size 128 octets for rate ½ 256 octets AOS, frame size 512 octets for rate ½ 1024 octets and 2/3 768 octets USLP	CCSDS 211.0-B-6, CCSDS 211.1-B-4, CCSDS 211.2-B-3
PRS2	Proximity Return S-band Link	2200-2290 MHz rates (TBD)	SS-BPSK CDMA (~3Mcps) SS-SQPN (Appendix C)	LDPC rate ½ (256 octets plus 64-bit ASM)	AOS, frame size 128 octets USLP	CCSDS 415.1-B-1 CCSDS 131.0-B-3
PRS5	Proximity Return S-band Link	frequency range (TBD)	TBD	TBD	TBD	LunaNet and User Signal Structure Definition Document [AD1]
PRS6	Proximity Return S-band Link	2200-2290 MHz rates (TBD)	TBD	TBD	TBD	

LunaNet Proximity Links (4/4)

Interface Name	Interface Type	Targeted Frequency Range	Modulation	Coding ¹ , slicing (Code rate and codeword length)	Frame Size, AOS, USLP ²	Applicable Documents
		Note: exact center frequency to be determined based on user requirements, conops, and are subject to coordination.		Slicing is recommended (when approved, frame size can be other than shown in frame column)	AOS and USLP to be supported	CCSDS 732.1-B-2 for USLP
PfKa1	Proximity Forward Ka-Band Link	23.15-23.55 GHz 1 Msps < Rs < (upper limit of rate TBD)	Filtered OQPSK	LDPC code rates 1/2 (4096 octets plus 64-bit ASM) LDPC code rates 2/3 (3072 octets plus 64-bit ASM), or LDPC code rate 4/5 (2560 octets plus 64-bit ASM) LDPC rate 7/8 (1020 octets plus 32-bit ASM) or uncoded (2048 octets plus 32-bit ASM)	AOS, frame size 2048 octets for LDPC rate ½, 2/3 and rate 4/5. AOS, frame size 892 octets (LDPC rate 7/8) or 2048 octets (uncoded) USLP	CCSDS 401.0-B-31 CCSDS 131.0-B-3
PfKa2	Proximity Forward Ka-Band Link	23.15-23.55 GHz 1 Msps < Rs < (upper limit of rate TBD)	Filtered OQPSK/ GMSK (Modulation on suppressed carrier)	Convolutional Code CCSDS VCM (DVB-S2, SCCC, or LDPC-VCM) to be selected for higher rates and higher coding performance ⁵ (TBD)	AOS, frame size (TBD), or 2048 octets (uncoded) USLP	CCSDS 131.0-B-3 CCSDS 131.2-B-1
PRKa1	Proximity Return Ka-Band Link	27.0-27.5 GHz 1 Msps < Rs < (upper limit of rate TBD)	Filtered OQPSK	LDPC code rates 1/2 (4096 octets plus 64-bit ASM) LDPC code rates 2/3 (3072 octets plus 64-bit ASM) LDPC code rate 4/5 (2560 octets plus 64-bit ASM) LDPC rate 7/8 (1020 octets plus 32-bit ASM), or uncoded (2048 octets plus 32-bit ASM)	AOS, frame size 2048 octets for LDPC rate ½, 2/3 and rate 4/5 AOS, frame size 892 octets (LDPC rate 7/8) or 2048 octets (uncoded) USLP	CCSDS 131.0-B-3 CCSDS 131.2-B-1
PRKa2	Proximity Return Ka-Band Link	27.0-27.5 GHz 1 Msps < Rs < (upper limit of rate TBD)	Filtered OQPSK/ GMSK (Modulation on suppressed carrier)	Convolutional Code CCSDS VCM (DVB-S2, SCCC, or LDPC-VCM) to be selected for higher rates and higher coding performance ⁵ (TBD)	AOS, frame size (TBD), 2048 octets (uncoded) USLP	CCSDS 131.0-B-3 CCSDS 131.2-B-1

LunaNet PNT Services

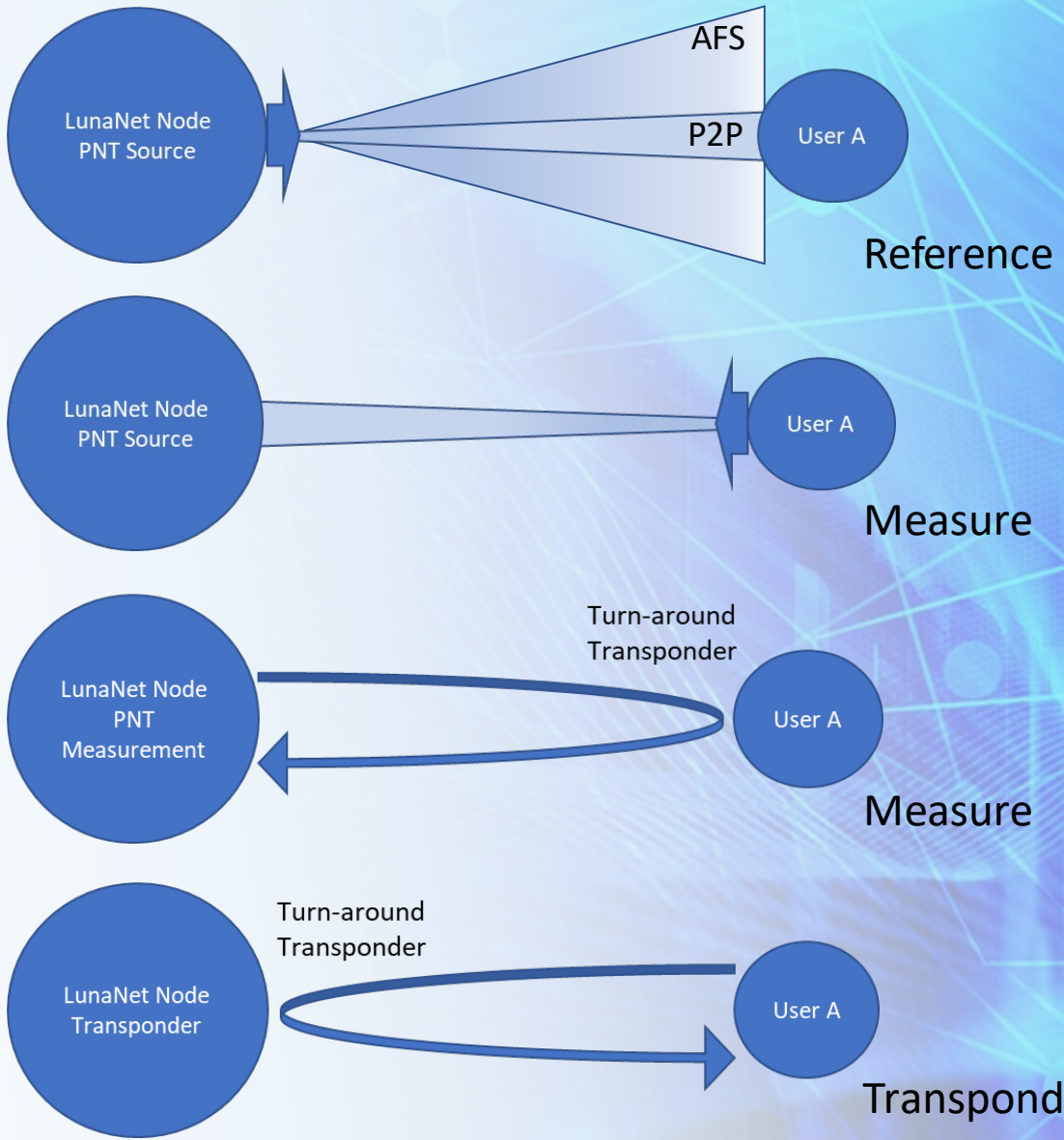


Augmented Forward Signal (AFS)
Lunar Augmented Navigation Service (LANS)
Lunar Network Service Provider (LNSP)
Messages (MSG)
Peer to Peer (P2P)
PseudoRandom Noise Code (PN)

2283.5-2500 MHz

LunaNet PNT Services

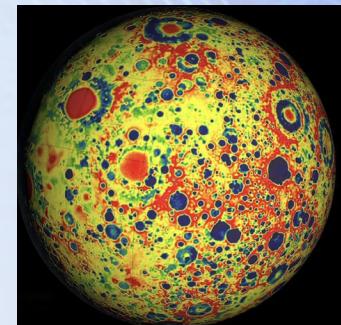
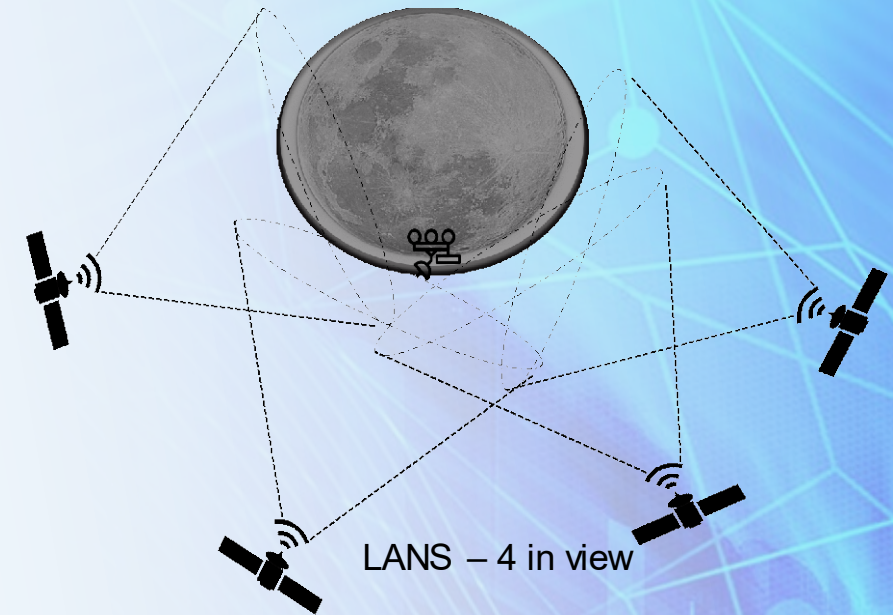
PNT Service ID	Services Reference: LunaNet Provider Transmits Signal Measurement: LunaNet Provider Measures and Sends to User Transponds: LunaNet Provider Coherently Transponds Signal from user [NOTE: Pseudo-Range means 1-way ranging.]
1wDRef	1-Way Doppler Reference
1wRTRef	Pseudo-Range and Timing Reference
1wDMeas	1-Way Doppler Measurement
1wRTMeas	Pseudo-Range Measurement
2wDMeas	2-Way Doppler Measurement
2wRMeas	Range Measurement
2wD-XPND	2-Way Coherent Doppler Transponder
2wNRR-XPND	Non-Regenerative Range Transponder
2wRR-XPND	Regenerative Range Transponder
TRef	Time Transfer Reference
Nav-G<x>	Supplemental Navigation Products
Loctn	Location Service



Lunar Augmented Navigation Service (LANS)

A lunar analog to terrestrial GPS/GNSS with associated benefits from broadcast signals and messages:

- Enables a lunar service volume that can extend beyond the local lunar region
- Addresses navigation and time accuracy and latency of surface and orbiting users
 - Overcomes link proliferation issues to support metric tracking
 - Reduces reliance on Earth assets
 - Enables flexible mission concepts – not limited by light time delays for dynamic activities, Earth processing time, occulted line-of-sight, or lighting conditions
- Enables network service-based communications
- Enables network and mission autonomy
- Enables user to seamlessly transition from GNSS to LANS for PNT
- LunaNet defines messages and signal structure for interoperability
- Reliant on definition and maintenance of lunar reference frame and time system



Zuber, et al

LunaNet Messages Overview

Suite of Standardized Messages

Concept is adaptable to new messages/changing needs

Message ID	Message Title
MSG-G1	LunaNet Network Access Information
MSG-G2	Health and Safety
MSG-G3	MAntennaProperties
MSG-G4	SOrbit Ephemeris+Clock correction
MSG-G5	MOrbit Almanac
MSG-G6	SOrbit Almanac
MSG-G7	SOrbitState /Location
MSG-G8	Time and Frequency Synchronization (fine)
MSG-G9	Time and Frequency Synchronization (frame)
MSG-G10	Maneuver
MSG-G11	SAttitude State/Ephemeris
MSG-G12	MAttitudeEphem
MSG-G13	Observations
MSG-G14	Conjunction
MSG-G15	Maplet
MSG-G16	Map Comprehensive

Message ID	Message Title
MSG-G17	Ancillary info
MSG-S18	Search and Rescue Alert
MSG-S19	Acknowledge- of SAR - LvL1
MSG-S20	Acknowledge- of SAR - LvL2
MSG-G21	User Message Request
MSG-G22	Acknowledge- of non-SAR MSG
MSG-G23	GNSS Augmentation
MSG-G24	Detection Alert
MSG-G25	Science
MSG-G26	UIS Request
MSG-G27	UIS Response
MSG-G28	User Schedule Notice
MSG-G29	FF Commands

S = single
M = multi

Industry Feedback on Version 1 and Plans

Following the release of Version 1 (September 2021), the NASA team received and reviewed industry inputs.

- Viewpoints were brought into LIS working groups and some are reflected in updated draft.
- Identification and dispositioning of Version 1 comment topics on following slide.
- Forums on specific topics will be scheduled to allow industry presentations and inputs.

Industry Feedback Topics on Version 1 and Dispositions

Updates Included in Latest Draft:

- Background/Scope of Document
- Unified Space Data Link Protocol (USLP)
- Augmented Forward Signal (AFS) and Lunar Augmented Navigation System (LANS)
- Coding and Modulation
- Spectrum

Future Work:

- Crosslinks
- Messaging Service
- Multiple Access/Service Access
- Networking
- Optical Communications
- Position, Navigation, and Timing
- Security
- Surface Beacons

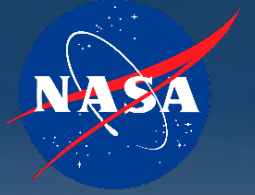
Summary

The updated draft is now online at: <https://go.nasa.gov/3wtEfEv>

- This is not the final version. We will continue to work with other government agencies, industry, and academia to refine the document.
- The LunaNet Interoperability Specification has grown to be more than a NASA document.
- Continued input from industry is requested and desired to maximize overall network interoperability, performance, and capacity.



If you have a question, please place it in the chat.



Thank You!

For any follow-up questions or comments, please email:
nasa-commercialsynergies@mail.nasa.gov