Lunar Communication & Navigation Network - Lunar Pathfinder

Lunar Pathfinder is a Lunar Communication relay satellite funded according to a Public-Private Commercial Partnership between Surrey Satellite Technology Limited (SSTL) and the European Space Agency (ESA) acting as an anchor customer

By insuring the insertion into orbit of Lunar Pathfinder, NASA cooperates with the mission and is also a User of Lunar Pathfinder for its missions

The End-to-end mission architecture is established and managed by SSTL

The Lunar Pathfinder spacecraft is designed to provide affordable communications services to lunar missions via S-band to lunar assets on the surface and in orbit around the Moon, and an X-band link to Earth

Lunar Pathfinder is a first step towards ESA's ambitious Moonlight vision to create a network of communications and data relay satellites serving users worldwide to facilitate access to the Moon. Such satellites could also provide navigation data for lunar exploration, just as today we navigate using Galileo and GPS on Earth

User Terminals compatible with Lunar Pathfinder are currently in development in Europe and the United States as part of independent development activities (not part of Lunar Pathfinder service)

Launch date: Q4 2025

Exploitation: Q1 2026 up to Q3 2034 (or beyond)

Pathfinder will orbit around the Moon in Elliptical Lunar Frozen Orbit (ELFO)

- Perilune altitude (km): 673.4 ; Apolune altitude (km): 7331.8
- Inclination (deg): 46.8 ; Orbital Period: 10h

Pathfinder orbit is designed to maximize communication windows over the South Pole yet enable visibilities over the complete Lunar Surface

Lunar Pathfinder provides a store & forward Earth-Moon relay for forwarding and returning data over orbital periods. I has three initial services at date of Launch:

- Autonomous Service: contact planning is managed by SSTL
- Scheduled Service: contact at an agreed time with Customer
- Emergency Service: high priority scheduled contact for emergency

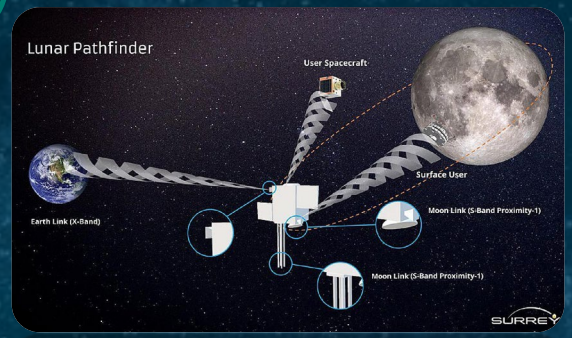
Additional bespoke services can be developed according to needs

Services & Conops

Mission overview

Users

Ambition



Physical Layer Details

Orbit & lifetime

Data exchange

Links

[Lunar Pathfinder mission | SSTL]

The Lunar Pathfinder services will be a mission enabler for polar and far-side missions, which, without direct line of sight of the Earth, would otherwise have to procure their own communications relay spacecraft

Lunar Pathfinder is complementary to Direct-to-Earth communication solutions and a credible alternative to institutional deep-space ground stations, offering orbiters and near-side missions a better availability, enhanced safety and improved data-rate

Lunar Pathfinder provides connectivity to Surface Users (rovers, landers) and Orbital Users

Lunar Pathfinder is compatible with Cubesat-class designs up to flagship missions

Coding: LDPC 2/3, k=4096;

Modulation: SP-L/PM or GMSK (BT=0.25);

Symbol rate = 2^N within [1; 4096] ksps (N from 0 to 12)

Adaptative rate is applied on the Return Link to maximize throughput

Datalink: Prox1 type4 (USLP) with ARQ support in Full duplex only (based on COP-P Go-back-N)

Operations: Full duplex, RTN simplex, FWD simplex, Dual Simplex

Polarization: Sband = LHCP

Patchable link layer firmware to enable protocol evolutions

Sband (worst-case): G/T = -6.5dB/K; EIRP = 24.6dBW

Data exchange with customer is handled through file exchange over SFTP servers

- Forward link: the customer provides the data to be uploaded as a file
- Return link: the customer retrieves the data sent by the satellite as a file

The User is free to add any upper-layer into this file for data multiplexing, end-to-end encryption; SSTL will manage the end-to-end transfer of this data as a global cargo

The Lunar Pathfinder infrastructure include a global data transfer integrity check to secure its safe recovery from each side of the link

Lunar Communication & Navigation Network – Moonlight LCNS

Upon successful ESA Ministerial Conference (Nou 2022), ESA Moonlight LCNS Program has been confirmed. Public-Private Partnership: Private sector as service provider and providing co-funding for infrastructure development. ESA Anchor customer to provide services to ESA and ESA Partners missions

Moonlight Service Requirements have been consolidated, and an Invitation To Tender (ITT) for Moonlight Service Procurement has been issued for Industry. Proposal process on-going with closing date in Q4 2023

The kick-off of phase B2/C/D is expected in Q1 2024

Moonlight LCNS will be developed according to an incremental approach from Initial Operational Services (IOC) to Full Operational Services (FOC)

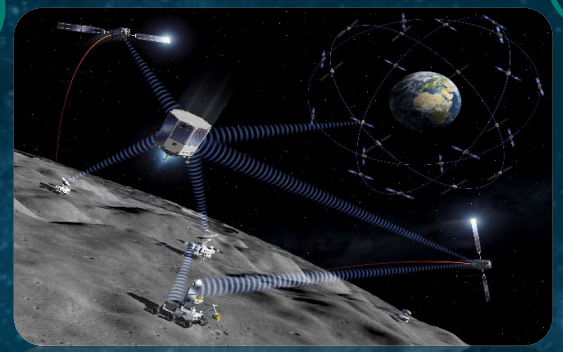
- ✓ **Initial Services in 2027 and Full Services in 2030**
- ✓ **Exploitation: 2027 up to 2045 (or beyond)**

Phase AB1 resulted in a baseline with Elliptical Frozen Orbits (ELFO) with optimised coverage on the lunar south pole.

The final orbit is to be defined during the B2 phase

Moonlight LCNS provides communication and navigation services to its Users

The targeted Users go beyond Lunar Pathfinder with an increased and upgraded set of services



[Moonlight White Paper]

[ESA - Moonlight]

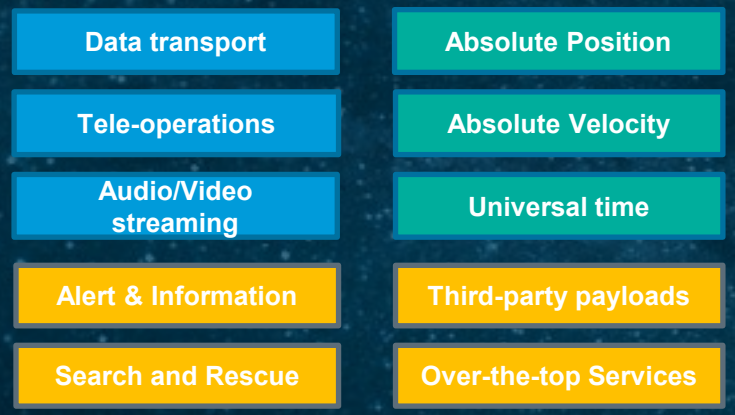
Data transport	Absolute Position
Tele-operations	Absolute Velocity
Audio/Video streaming	Universal time
Alert & Information	Third-party payloads
Search and Rescue	Over-the-top Services

Protocols & RF characteristics: as per the LunaNet Interoperability Standard defined between NASA and ESA to ensure interoperability of the global Lunar Communication & Navigation Services

[LunaNet Interoperability Specification | NASA]

Data exchange and supported protocols for the different services are to be consolidated during the B2 phase.

Lunar Communication & Navigation Network – Moonlight LCNS



Lunar Communication Services

Capabilities of Moonlight's lunar communication services will include include:

- Data Transfer: bulk data transfer between two user assets located anywhere within the defined lunar service coverage or on Earth; not intended for real time needs.
- Data Streaming: real-time audio and video bi-directional streaming between two user assets located anywhere within the defined lunar service coverage or on Earth; could satisfy time-sensitive user needs.
- Tele-operations: real-time streaming service, specifically intended for the real time operation of lunar assets (e.g., rover operations, deployment of structures, experiments requiring asset manipulation); encompasses telemetry/telecommand real-time channel and streaming channel for visual and audio.

Lunar Navigation Services

Capabilities of future lunar navigation services will provide GNSS-like services similar to those provided today on Earth (such as Galileo or Global Positioning System) including:

- Absolute Position: obtaining the absolute position in real-time (e.g., for georeferencing, navigation applications)
- Absolute Velocity: determining the absolute velocity in real-time (e.g., for mobility or monitoring applications)
- Universal Time: real-time determination of accurate time; for example, synchronised with Earth Coordinated Universal Time.
- Post-Processing Position, Navigation, Timing Service: included capabilities to provide a much more accurate enhanced post-processing time Position, Navigation, Timing services.
- Lunar Surface Augmentation Services: capability enhancements by local lunar surface augmentation services (for example, via surface beacon stations) could provide very accurate Position, Navigation, Timing services for the local service area.
- Small Navigation Receivers: All those services may be obtained with small navigation receivers, simple evolutions of standard spaceborne GNSS receivers.