Moonlight

Pioneering Communication and Navigation for Lunar Exploration

Moonlight is the European Space Agency's (ESA) Program enabling connectivity and navigation services from the lunar surface and to the Earth by delivering a constellation of satellites around the Moon.

Why Moonlight?

With over **400 lunar missions** planned by space agencies and private companies in the next twenty years, Moonlight represents a crucial step toward **sustainable lunar exploration** and the development of a robust lunar economy.

The program aims to support both **institutional** and **commercial** missions, enabling precise autonomous landings, surface mobility, and high-speed, low-latency data transfer between Earth and the Moon.

This infrastructure will be essential not only for humanity's return to the Moon but also for **establishing a stable and long-term presence**.

The Role of the European Consortium

As part of the above strategy, on October 15, 2024, Telespazio signed a contract with ESA for the development of a satellite constellation aiming to provide **communication and navigation services for future lunar missions**.

The project, called Lunar Communication Navigation Service (LCNS), involves a consortium of specialized companies, with Telespazio as the prime contractor and overall system integrator.

The consortium includes partners such as operators **Hispasat**, **Viasat**, and as manufacturing **Thales Alenia Space Italia**, **Surrey Satellite Technology Limited**, **Qascom**, **MDA**, **KSat**, **Telespazio UK**, **Telespazio Iberica**, and as University **SDA Bocconi**, **POLIMI**, **Sapienza CRAS**, and **Sapienza SIA** for the design, realization, and operational qualification of the system.

Connecting the Future of Lunar Exploration

LCNS lays the foundation for a **stable and sustainable future in lunar exploration**, fostering international cooperation and creating new commercial opportunities within the lunar economy.

With an innovative infrastructure, this Programme enables future missions to rely on a dependable network for communication and navigation, supporting both human and robotic exploration and advancing new goals in space exploration.

The LCNS Service Infrastructure

LCNS service infrastructure is built in a way that non-homogeneous capabilities can be used in harmonised way exploiting the potentiality of Moon exploration. The NAV perfectly complement the COM part as positioning over the Moon is of a paramount importance to explore lunar surface in a reliable way while communication ensure the way to control lunar activities.

The LCNS infrastructure consists of three key elements:

- **Lunar Space Segment:** a constellation of five satellites, with four dedicated to navigation and one to communication. These satellites will provide high-speed, low-latency communication services, along with precise navigation signals that will enable autonomous landings and surface mobility.

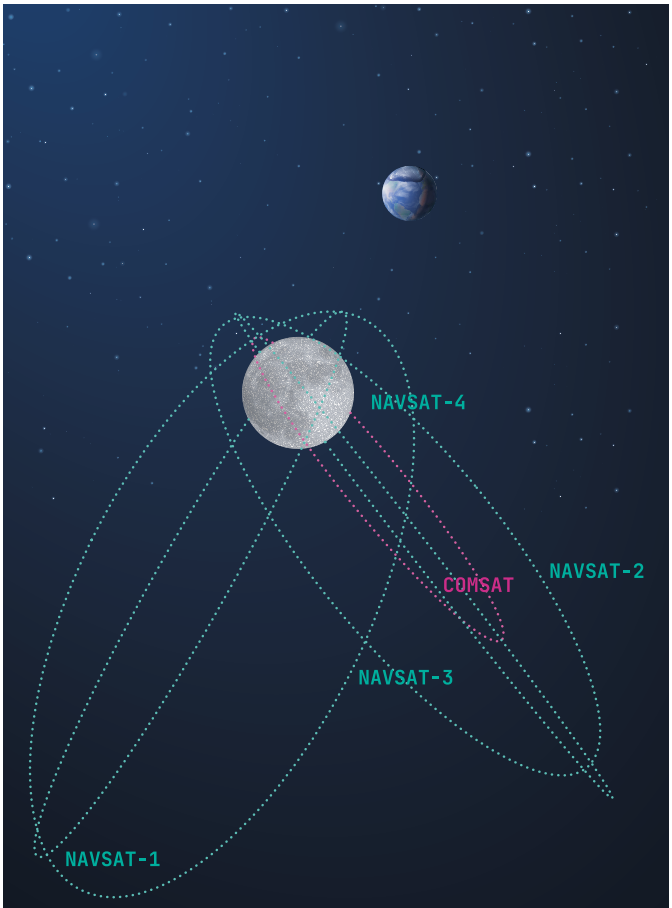
  The satellites will be positioned to ensure extensive coverage of the lunar South Pole, an area of particular interest for future missions due to resources like ice in the “eternal darkness” craters and “peaks of eternal light,” which are ideal for solar energy harvesting.

  The constellation of LCNS satellites is designed to provide optimized service coverage of the lunar south pole, both for communication and navigation.

- **Lunar Earth Ground Segment:** three ground stations on Earth together with a state-of-the-art Ground Segment deployed over commercial cloud, playing a key role in monitoring and managing the entire infrastructure.

  The constellation is planned to be controlled at the Telespazio Fucino Space Centre, which was instrumental in transmitting images of the Apollo 11 Moon landing in 1969.

  The EGS infrastructure will be crucial in ensuring the continuity of services and the connection between the Moon and Earth, coordinating all operations of the constellation and supporting the communications and navigation network.



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 12hr and a semi-major axis of about 6000 km.

- **Lunar User Segment:** granting LCNS services access for end-users through Qualified Type Approval lunar user terminals (LUT) aiming first to validate the communication and navigation services once during the in-orbit qualification and then to provide end-to-end services to final user.

Communication Service Capabilities

The LCNS Services is provided with high availability (>95%) and temporal coverage ~ 16 hours/day (non continuous), with continuous slots of at least 8 hr/day. The following service characteristic are planned to be supported:

- Data Relay Duplex Service: Simplex or Full
- K-band service profile: Single-Access service with a data-rate up to 55/3 Mbps (Moon-Earth / Earth-Moon)
- S-band service profile: Single-Access service with a data-rate up to 2000/100 kbps (Moon-Earth / Earth-Moon)
- Data Volume: Non-Real-Time service data volume of 150 GBytes per Earth Day
- Delivery Time for Non-Real-Time Data: Non Real-Time data delivery within 16 hours
- Availability: Data Relay Service with an availability of 94% over 30 days
- QoS for prioritization: System support Nominal and Critical QoS
- Latency: Real time data transferred in less than 5 seconds
- Maximum number of concurrent sessions: up to 1 Full-duplex K-band link and 2 Full-Duplex S-band link

A Direct to Earth (DTE)/Direct with Earth (DWE) service complement the LCNS data relay services for improving temporal and geometrical coverage.

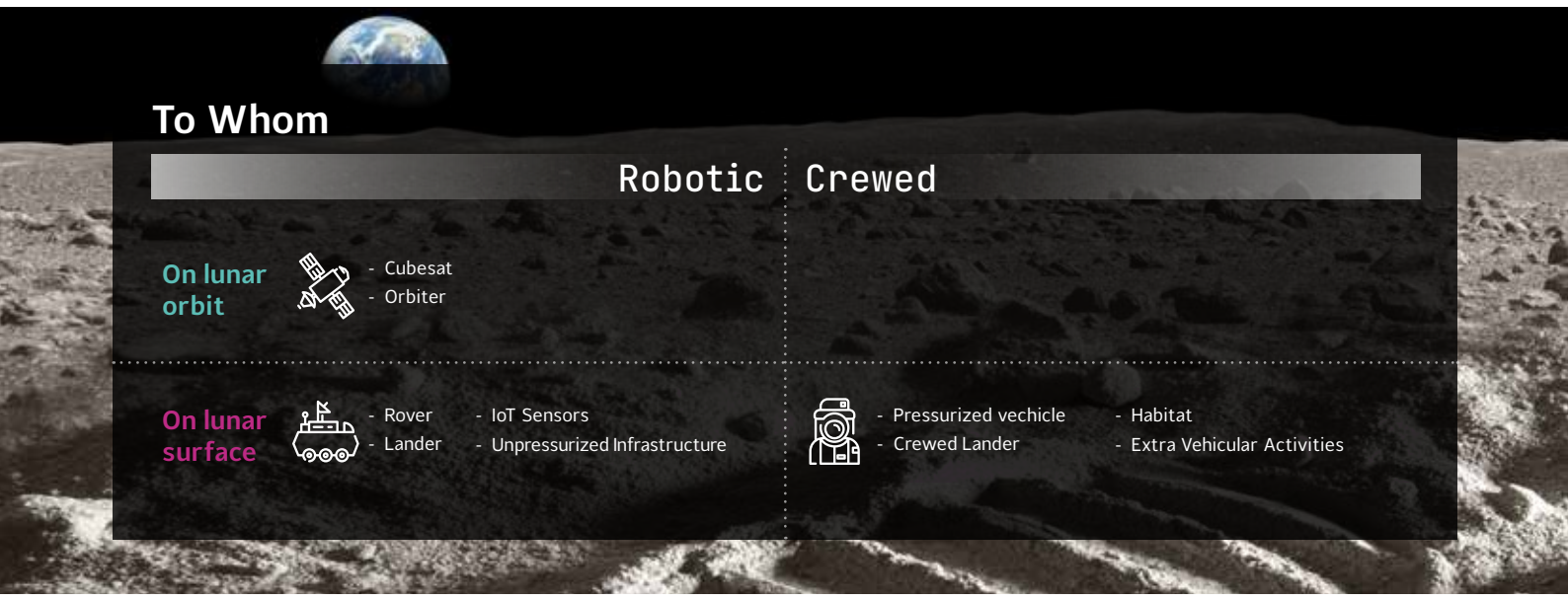
Navigation Service Capabilities

Two categories of navigation services with a minimum availability of 95% over 30 days are provided:

- Real time services:
  - One-Way Ranging (OWR)
  - Position, Velocity and Time (PVT)
  - Time Dissemination Service (TS)
  - Two-Way Measurement (TWM – To be confirmed)
  - Navigation Service Availability and Performance Prediction
- Non-real-time services granting highly accurate PVT post processing

The PVT performances, with a 95% confidence on lunar South pole as follows:

- Horizontal position accuracy < 10 m (static user) to < 50 m (ascending/descending users)
- Vertical position accuracy < 100 m
- Horizontal velocity accuracy ~ 1 m/s (all users)
- Timing accuracy: < 0.4 μs (static user) to < 15 ms (ascending/descending users)



Interoperability and International Cooperation

LCNS Radio Frequency 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.

LCNS will be part of the LunaNet and as that will adhere to **LunaNet Specification** (LNIS) for the service provision.

- The services provided by LCNS will guarantee interoperability with the other LunaNet Service Provider (LNSP), will conform to the LunaNet framework of mutually agreed-upon standards, protocols, and interface specification that enable interoperability.
- The flexible approach of LunaNet, of providing incremental services, starting from an IOC phase until a sustained capability phase, is followed in the LCNS setup, which will undergo a progressive deployment of the communication and navigation services from the IOC to the FOC phase.

Service Availablity

LCNS Service is released in a staggered approach as below specified:

- **Initial Operational Capabilities:** Launch planned by Q1 2029 with operational service ready by Q2 2029
- **Final Operational Capabilities:** Launch planned by Q2 2030 with operational services ready by Q4 2030

Key Benefits of the LCNS Program

- **Enhanced Communication:** LCNS enables high speed data transmission, allowing lunar missions to communicate effectively. This improves operational efficiency and minimize the need for direct Earth communications.
- **Precise Navigation:** the LCNS constellation provides highly accurate positioning signals, reducing the complexity and cost of navigation for landers, rovers, and orbiters. It decreases the risk of lunar exploration by ensuring PVT services.
- **Commercial Opportunities:** By creating reliable lunar communication and navigation services, Moonlight opens new possibilities within the growing lunar economy, facilitation technological advancements and sustainable exploration.

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