ESA Lunar PNT on-going activities: The ESA Moonlight Programme

Dr Javier Ventura-Traveset
Head of Navigation Science Office &
ESA Lunar PNT Coordinator
ESA Navigation Directorate
European Space Agency

Werner Endere
Head of Navigation Support Office
ESA Directorate of Operations
European Space Agency
Moonlight / LCNS
Step 1: Moonlight / LUNAR PATHFINDER – GNSS In Lunar Orbit demonstration
Low-rate satellite communications service (Including some LCNS Critical technologies / Moon GNSS Receiver)

Pathfinder Development  \rightarrow  Pathfinder Service

2024

Step 2: Moonlight / LCNS (dedicated lunar Constellation)
High-data rate satellite communications and navigation service

LCNS Phase A/B1  \rightarrow  LCNS Phase B2/C/D/E1  \rightarrow  LCNS Initial Services

2020 2021 2022 2023 2024 2025 2026 2027 2028
Future Lunar Pathfinder IoD GNSS Payload and Laser Retroreflector experiment with NASA (launch 2024)

First ever demonstration of GNSS reception on Lunar orbit.

Main Earth Link
7190-7235 MHz (forward 8 kbps)
8450-8500 MHz (return ≤ 5 Mbps)

UHF (Proximity-1)
390-405 MHz (forward 1 kbps)
435-450 MHz (return ≤ 2 Mbps)

S-Band
2025-2110 MHz (forward 1 kbps)
2200-2290 MHz (return ≤ 2 Mbps)
GNSS Receiver and GNSS antenna high-level specifications

### High-sensitive GNSS Receiver

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition sensitivity</td>
<td>15dBHz</td>
</tr>
<tr>
<td>Tracking sensitivity</td>
<td>15dBHz</td>
</tr>
<tr>
<td>3D Position accuracy</td>
<td>&lt; 100m RMS</td>
</tr>
<tr>
<td>3D Velocity accuracy</td>
<td>&lt; 0.1 m/s RMS</td>
</tr>
<tr>
<td>Mass</td>
<td>1.3 Kg</td>
</tr>
<tr>
<td>Size</td>
<td>24x12x7cm</td>
</tr>
<tr>
<td>Power</td>
<td>&lt; 12W</td>
</tr>
</tbody>
</table>

### High-gain GNSS Antenna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 boresight gain</td>
<td>15 dBi</td>
</tr>
<tr>
<td>L5 boresight gain</td>
<td>12 dBi</td>
</tr>
<tr>
<td>Polarization</td>
<td>RHCP</td>
</tr>
<tr>
<td>Mass</td>
<td>~2Kg</td>
</tr>
<tr>
<td>Size</td>
<td>26<em>26</em>28cm</td>
</tr>
</tbody>
</table>

The **on-board navigation filter** in the receiver implements Earth and Sun point mass and the Moon gravity field up to **10x10 order and degree harmonics**.
Satellite will be an elliptical lunar frozen orbit with the apoapsis over the lunar South Pole

Aposelene height : 7500 Km
Periselene Height: 500 Km
Eccentricity: 0.61
Inclination (deg): 57.8
Estimated performances: very accurate simulation LP

Accuracy in real time and in lunar orbit < 60 metres (rms)
Step 2: Moonlight / LCNS
To enable the delivery of Communications and Navigation Services that will support the current and next generations of institutional and commercial Lunar explorers.
Moonlight: an essential element of the contribution of Europe to future lunar exploration
✓ Initial set of capabilities identified by ESA for our industrial teams to focus on and elaborate further;

✓ The Phase A/B1 work aims at defining a feasible concept traceable to these capabilities;

✓ Further capabilities may be considered (e.g. outcome of the users workshops)
1. EARTH GROUND SEGMENT (EGS)

- Dedicated NAV Ground segment providing precise Orbit, time Synchronisation and NAV augmentation messages to Lunar orbiting satellites and Lunar ranging beacons
- Dedicated stations may also be needed to provide enhanced orbit accuracy (e.g. laser ranging, VLBI, ...).

2. MOONLIGHT CONSTELLATION (LSS)

- An initial constellation of 4 to 5 dedicated Lunar orbiting satellites may be envisaged (TBC)
- System should be upgradable to improve lunar coverage and services and internationally interoperable

3. LUNAR SPACE SEGMENT (LSS)

- LCNS satellites will include a Precise orbit determination and time synchronisation (dedicated close-loop from Earth G/S)
- Each satellite will include dedicated NAV Payload transmitting GNSS-like signals (1 way ranging) and, potentially, an enhanced 2-ways lunar NAV service

4. MOON SURFACE SEGMENT (MSS)

- 1 or 2 Lunar PNT ranging beacons might be deployed in specific areas (e.g. South pole, permanent sites) to improve ranging geometry
- Those may also help as lunar reference stations for selenodesy / ODTS and overall LCNS service monitoring

5. LUNAR USER SEGMENT (LUS):

- combined COM/NAV users
- NAV only user terminals may also be conceived

Capitalising on ESA’s unique GALILEO Expertise
LCNS Initial Mission Assumptions (1/2)

- Commercial & Institutional Missions
- Beyond 2026
- Support all Mission Phases

- Open Interface

- Scalability

- Interoperability

- Standardisation

- 1000Km Service Volume [to 70000Km]

- South Pole Coverage [to Far side & Global]
LCNS Initial Mission Assumptions (2/2)

Compatible with Earth GNSS

Precise timing (sub μs)

Position accuracy
Landing: 100m [to 30m]
Surface: 50m [to 10m]

Velocity accuracy
Landing: 0.5m/s
Surface: 0.1m/s

20Mbps/user [to 50Mbps/user]

10GB/hour [to 100GB/hour]

Security functions

Slotted Real time services
Kick off of Moonlight Phase A/B1 held on April 2021
Industrial teams include satellite operators (potential service providers) and large space&ground system integrators

Initial Moonlight services planned for 2026-2028
Recent ESA publications at Inside GNSS Journal

Across the Lunar Landscape Towards a Dedicated Lunar PNT System

December 7, 2020

By Inside GNSS

The second of a two-part article explains how an inertial system using existing Earth-GNSS constellations may be augmented with dedicated lunar orbiting satellites as well as lunar beacon ranging sources. A gradual deployment leads to a full autonomous lunar navigation system.

MIRIAM SCHÖNFILDT, ANTOINE GRENIER, ANAÏS DELÉPAUT, PIETRO GORDANO, RICHARD SWINDEN AND JAVIER VENTURA-TRAVESI ET EUROPEAN SPACE AGENCY