Lunar Pathfinder

Moonlight

Dr Javier Ventura- Traveset
Moonlight-Navigation Manager
European Space Agency
LUNAR EXPLORATION: A NEW PARADIGM

Oppportunities... ...competition...

It’s happening...

Public.... ...Private

Moon Monday #32: Japan’s Moonshot, China’s partnership goals, Artemis updates, and more

- On the success and failure of Japan’s first Moon landing attempt and China’s plans to establish a foothold on the Moon.
- Artemis updates and milestones.

March 2023

Moon Monday #31: A lunar-bound ispace craft, Chandrayaan 2 shortlisted for ISRO’s lunar project, a Sino-Russian mission, and more

- An ispace craft brings惊喜 to the moon.
- Chandrayaan 2 shortlisted for ISRO’s mission.
- Sino-Russian mission plans.

https://blog.jatan.space/moon-monday/archive?sort=new

NASA announcement for Artemis 2, continues its lunar exploration efforts, and more

- What lies ahead for NASA’s lunar exploration mission.
- Updates on the Artemis 2 mission.

April 2023

Moon Monday #30: Support a casually mentioned “new” moon and China’s plans, by sponsoring a small-scale, deeply cultural project or a Moon-based artwork and more

- Support for the casual mention of a new moon.
- China’s plans and updates.

Moon Monday #29: Starship Artemis, mission updates, and more

- Updates on the Artemis mission.
- Starship mission updates.

Moon Monday #28: Views of Luna from a Russian craft, mission updates, and more

- Views of the moon from a Russian craft.
- Mission updates.

Moon Monday #27: Moonscape maple nation, Artemis updates, a lunar water map, and more

- Updates on the Artemis mission.
- A lunar water map.
- Maple nation and the moon.

JAXA’s SLIM

NOVA-C

Intuitive Machines

Astrobotic

Pergamon Lanpoor
Next 10 years: A market prediction estimated now in **136 Billion Dollars** !!

The over 400 missions planned already for this decade, require all their own Com & Nav provision means!

The current model (each mission providing its own comm-nav means) is not cost effective!!

Solution: set-up dedicated Lunar COMM and NAV infrastructures: boosting lunar exploration and lunar economy!
### ESA Roadmap plans for Lunar Navigation Services

<table>
<thead>
<tr>
<th>Phase 1: Use of Existing Earth-GNSS (2025 – onwards)</th>
<th>Phase 2: Moonlight NAV Initial Services (2027 – 2035)</th>
<th>Phase 3: Moonlight NAV enhanced services (2035 – onwards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Lunar PNT services</td>
<td>Moonlight Lunar PNT services</td>
<td>Enhanced Moonlight Lunar PNT services</td>
</tr>
<tr>
<td>Use Earth-based GNSS (Galileo and GPS) signals and high-sensitive GNSS Receivers</td>
<td>Initial lunar orbit GNSS-like constellation supporting South Pole surface and cislunar orbit services</td>
<td>Enhanced Lunar NAV Satellites constellation (complemented by lunar surface elements) to provide Full lunar surface coverage and enhanced performances PNT performances</td>
</tr>
</tbody>
</table>

**Enhanced Services**

- **Lunar Pathfinder GNSS Payload IoD**
- **MOONLIGHT / LCNS IOC / FOC Services**
MOONLIGHT STEP 1:
Lunar Pathfinder

Lunar Pathfinder will be launched by Firefly Aerospace end of 2025!
Lunar Pathfinder Navigation Payload In-orbit Demonstration
All flight units now manufactured and tested

GNSS High-sensitive receiver Flight unit

GNSS High-gain Antenna Flight unit

Laser Retroreflector Flight unit (NASA)

Demonstration of GPS/Galileo PNT on a Lunar orbiting satellite

First time ever three ranging techniques (GNSS, Laser and X-band ranging) are used simultaneously on lunar orbit
How well will the GNSS Receiver perform on lunar orbit?

Lunar Pathfinder Orbit: 10 days simulation

Autonomous and real time Orbit Position accuracy <100 meters (rms)
**STEP 1: LUNAR PATHFINDER**
Low-rate satellite communications service + Moon GNSS Receiver

**STEP 2: MOONLIGHT LCNS CONSTELLATION**
High-data rate satellite communications and navigation service
Moonlight Vision

To enable the delivery of **Communications** and **Navigation Services** that will support the current and next generations of institutional and commercial Lunar explorers.
Moonlight Approach & Services

Service development Approach: ESA supporting infrastructure development and acting as Anchor customer

- Public-Private Partnership: Private sector as service provider
- A dedicated constellation of satellites around the Moon

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

Absolute Position
Absolute Velocity
Universal time

ESA UNCLASSIFIED – Releasable to the Public
FOCUSING ON THE SOUTH POLE

-70 deg
200 km
Moonlight LCNS High-level Service Requirements

- **High DataRate (KBand):** Upto 200Mbps/user
- **Low DataRate (Sband):** Upto 1Mbps/user
- **Security functions**
- **Slotted Real time services**

**Position accuracy** (95%)
- Orbiters: 100m
- Landing: 50m
- Surface: 10m (3m post-processing)

**Precise timing** (95%)
- (100 ns)

**One Way Ranging**
- SISE ODTs (95%)
  - IOC: 20 m
  - FOC: 10 m

Based on GNSS technologies
Moonlight: Mission Architectural Concept

Partners' MOC NOC

Site#1
- X/Ka

Site#2
- X/Ka

Site#3
- X/Ka

MOC NOC

NaviCom-1

ISL - Ka-Band

PFSS (S-Band)

Navi-1

XU1/2 - X02/1 (X-Band)

TT&C X-Band

DTE

Navi-2

PFSS (S-Band)

Navi-3

PFSS (E-Band)

Navi-2

PFSS (S-Band)

NaviCom-1

PFSS (E-Band)

ISL - Ka-Band

PFSS (E-Band)
Moonlight PNT services are at reach with proposed GNSS technologies! Extensive ESA and industrial simulations & analysis performed.

<table>
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<th>Surface Rover</th>
<th>Lunar Lander</th>
<th>Lunar Orbiter</th>
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<tbody>
<tr>
<td><img src="image1" alt="Surface Rover" /></td>
<td><img src="image2" alt="Lunar Lander" /></td>
<td><img src="image3" alt="Lunar Orbiter" /></td>
</tr>
<tr>
<td>Real time &lt; 10 m (95%)</td>
<td>&lt; 50 m (95%)</td>
<td>Real time &lt; 100 m (95%)</td>
</tr>
<tr>
<td>Post-processing &lt; 3 m (95%)</td>
<td>Landing accuracy</td>
<td>LLO accuracies</td>
</tr>
<tr>
<td><img src="image4" alt="Station 1" /></td>
<td><img src="image5" alt="Formal precision of position (3 sigma)" /></td>
<td><img src="image6" alt="LLO accuracies" /></td>
</tr>
<tr>
<td>3-5 meters</td>
<td>~20 meters</td>
<td>30-60 meters</td>
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Ref: Navigation Performance of a Lunar Surface Rover Using LCNS Positioning Assuming Realistic ODTS Performances, EUROPEAN NAVIGATION CONFERENCE 2023


MOONLIGHT will be developed to comply with LunaNet Interoperability Specifications.

Joint NASA and ESA cooperation initiative with the support also of JAXA. All our three systems will provide interoperable lunar GNSS-like Signals and messages, allowing common receivers and enhanced performances.
First-ever lunar PNT interoperability demonstration could take place in 2028 (under joint assessment by JAXA, ESA and NASA)

(Source: JAXA)
Moonlight VIDEO
Thank you!