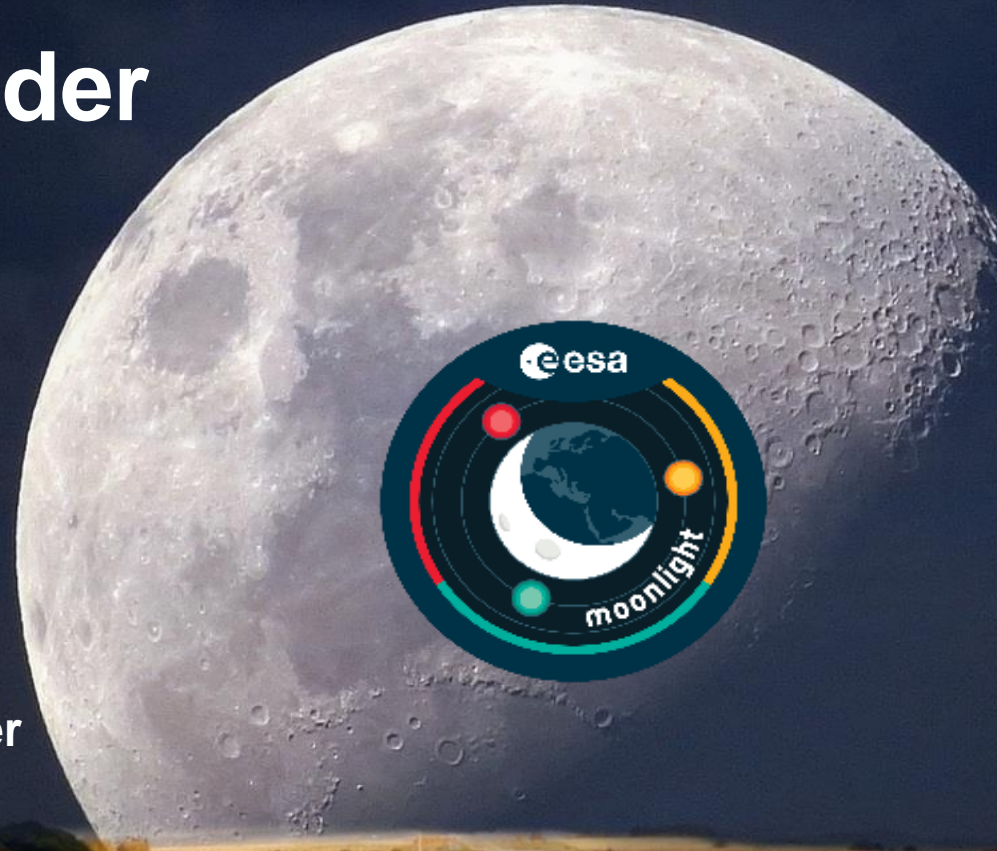


Lunar Pathfinder

Moonlight



Dr Javier Ventura- Traveset
Moonlight-Navigation Manager
European Space Agency

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→ THE EUROPEAN SPACE AGENCY

LUNAR EXPLORATION: A NEW PARADIGM



Moon Monday #125: ispace Japan's Moonshot, China's partnership push, Artemis updates, and more
 On the successes and failures of ispace's first Moon landing attempt, and related tangents and lessons for NASA's CLPS craft.
 JATAN MEHTA MAY 1

April 2023
Sponsor Moon Monday
 Support a community resource that's free and shows zero ads. By sponsoring, you'll reach deeply enthusiastic people who endorse our Moon's unique and...
 JATAN MEHTA APR 27

Moon Monday #124: Starship Artemis, mission updates, and more
 How NASA's road to putting humans on the Moon goes through SpaceX Starship, and why it matters to get it right.
 JATAN MEHTA APR 24

Moon Monday #123: Views of Luna from a Korean craft, mission updates, and more
 Science mode is ON for South Korea's first lunar orbiter KPLD, whose instruments have begun studies of our Moon.
 JATAN MEHTA APR 17

Moon Monday #122: Moonstruck maple nation, Artemis updates, a lunar water map, and more
 On March 28, the Canadian Space Agency announced long-term budgets to accelerate the country's lunar exploration endeavors.
 JATAN MEHTA APR 10

Moon Monday #121: NASA announces crew for Artemis II, centralizes its lunar exploration efforts, and more
 In what felt like an Apple-esque presentation, NASA announced the four astronauts that will travel around our Moon and back as part of the agency's...
 JATAN MEHTA APR 3

March 2023
Moon Monday #120: A lunarbound ispace craft, Chandrayaan 3 liftoff in sight, an Aussie lunar outpost, a Sino-Russian station, and more
 ispace Japan's Hakuto-R lunar lander successfully entered orbit around our Moon on March 21, making it the second such private company following...
 JATAN MEHTA MAR 27

Moon Monday #119: Mission updates, NASA's wishlist for Luna, science galore, and more
 The U.S. Presidential FY 2024 budget request seeks \$27.2 billion in funding for NASA from the U.S. Congress, a 7% increase over the \$25.4 billion...
 JATAN MEHTA MAR 20

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



OPPORTUNITIES ...
 ... COMPETITION

It's happening ...

PUBLIC ...
 ... PRIVATE



Lunar Market Report Update (NSR, March 2023)



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

Source: Lunar Markets, 3rd Edition, March 2023: [Lunar Markets, 3rd Edition - NSR](#)

Importance of Lunar Communication and Navigation dedicated infrastructure: a change of paradigm



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

Solution: set-up dedicated Lunar COMM and NAV infrastructures: boosting lunar exploration and lunar economy !

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

Commercial Lunar Payload Services

- CLPS-delivered science and technology payloads

Large-Scale Cargo Lander

- Increased capabilities for science and technology payloads

Humans on the Moon - 21st Century

First crew leverages infrastructure left behind by previous missions

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Early South Pole Mission(s)
- First robotic landing on eventual human lunar return and In-Situ Resource Utilization (ISRU) site

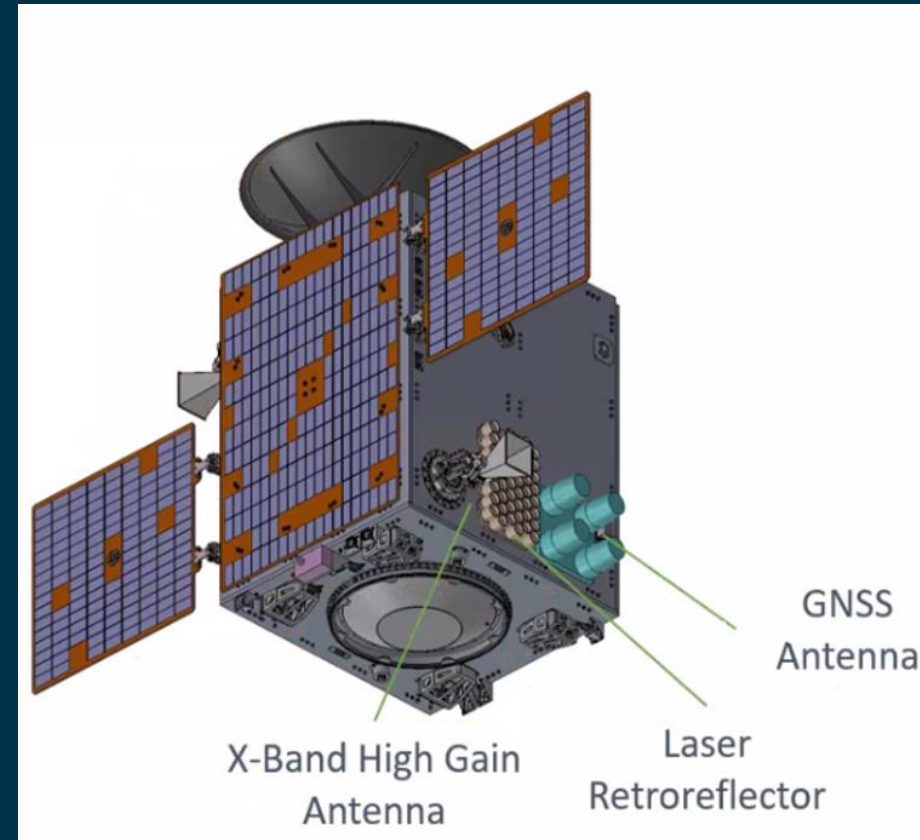
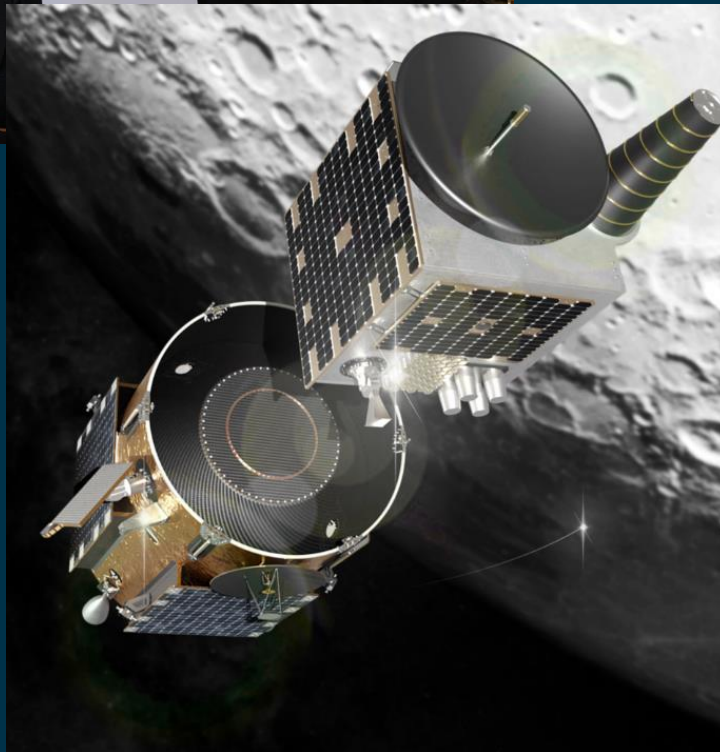
ESA Roadmap plans for Lunar Navigation Services



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

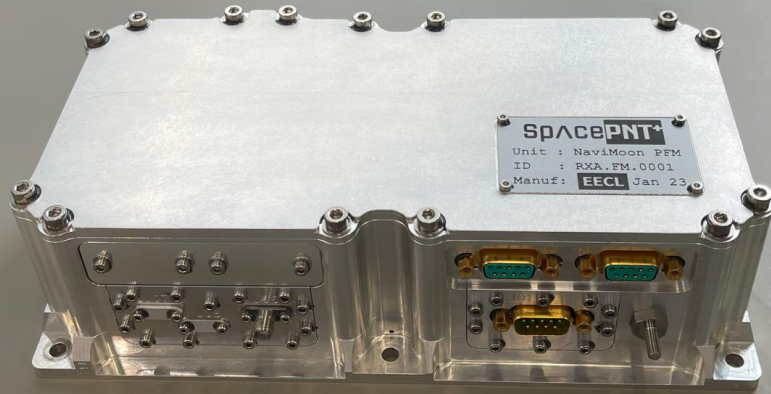
MOONLIGHT STEP 1: Lunar Pathfinder

Lunar Pathfinder will be launched by
Firefly Aerospace end of 2025 !

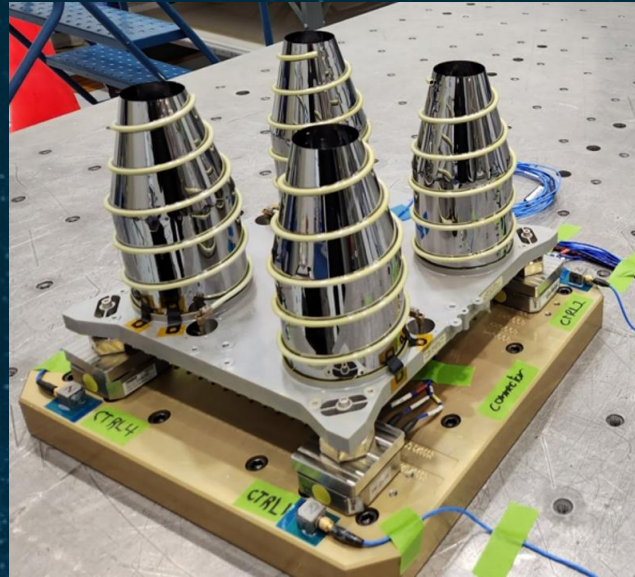


Lunar Pathfinder Navigation Payload In-orbit Demonstration

All flight units now manufactured and tested



GNSS High-sensitive receiver
Flight unit



GNSS High-gain Antenna
Flight unit



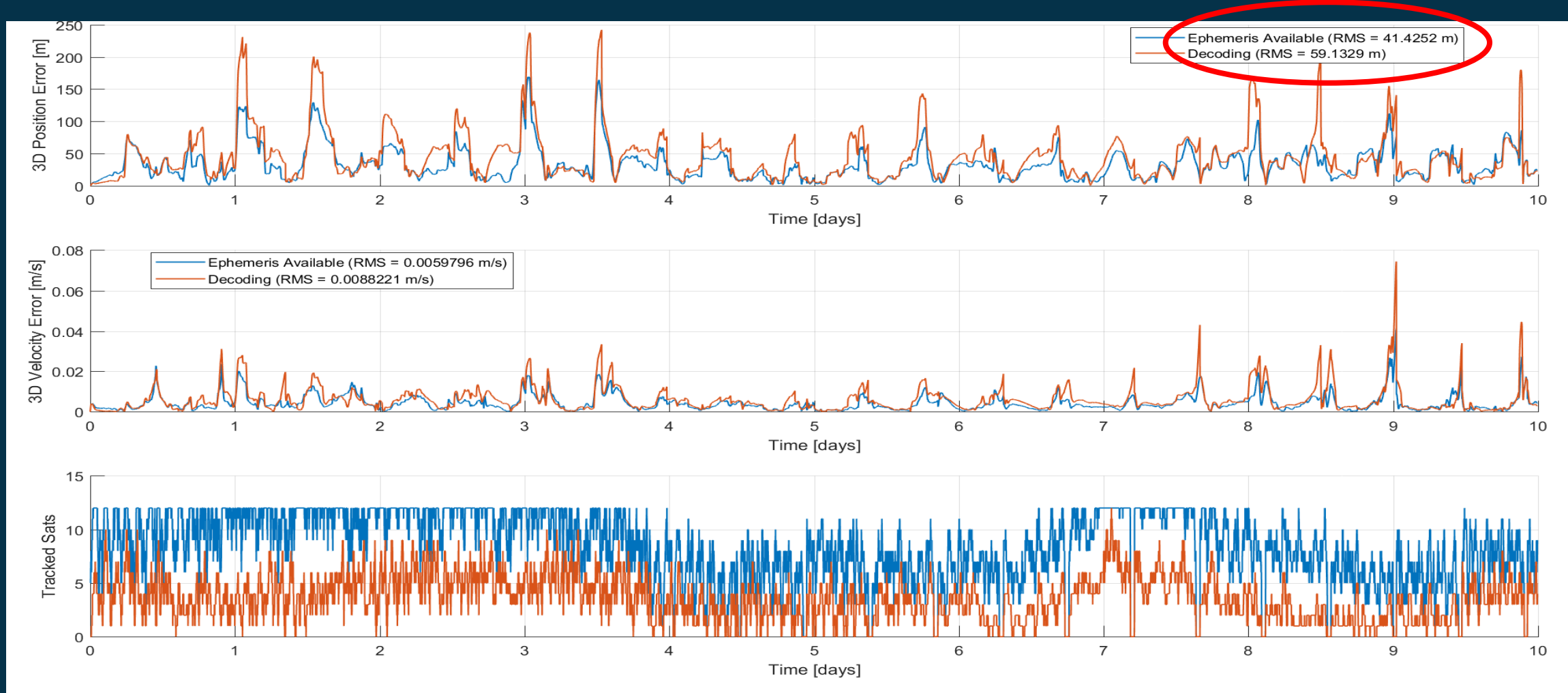
Laser Retroreflector
Flight unit (NASA)

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)

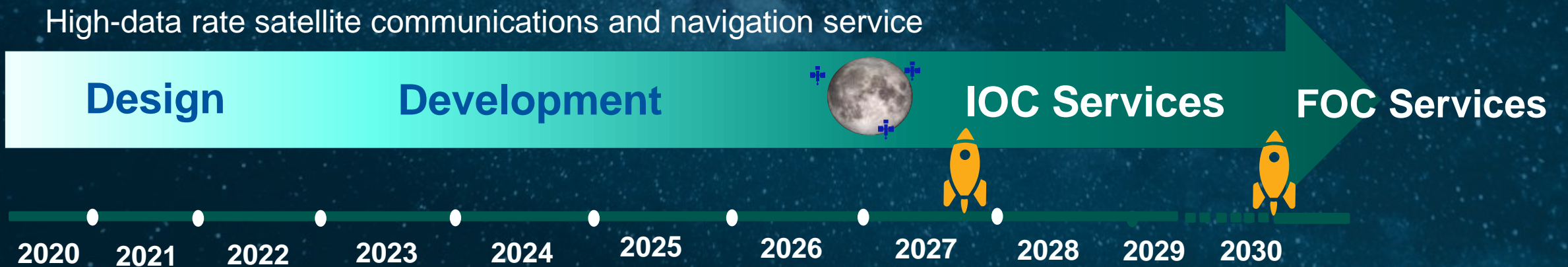
STEP 1: LUNAR PATHFINDER

Low-rate satellite communications service + Moon GNSS Receiver

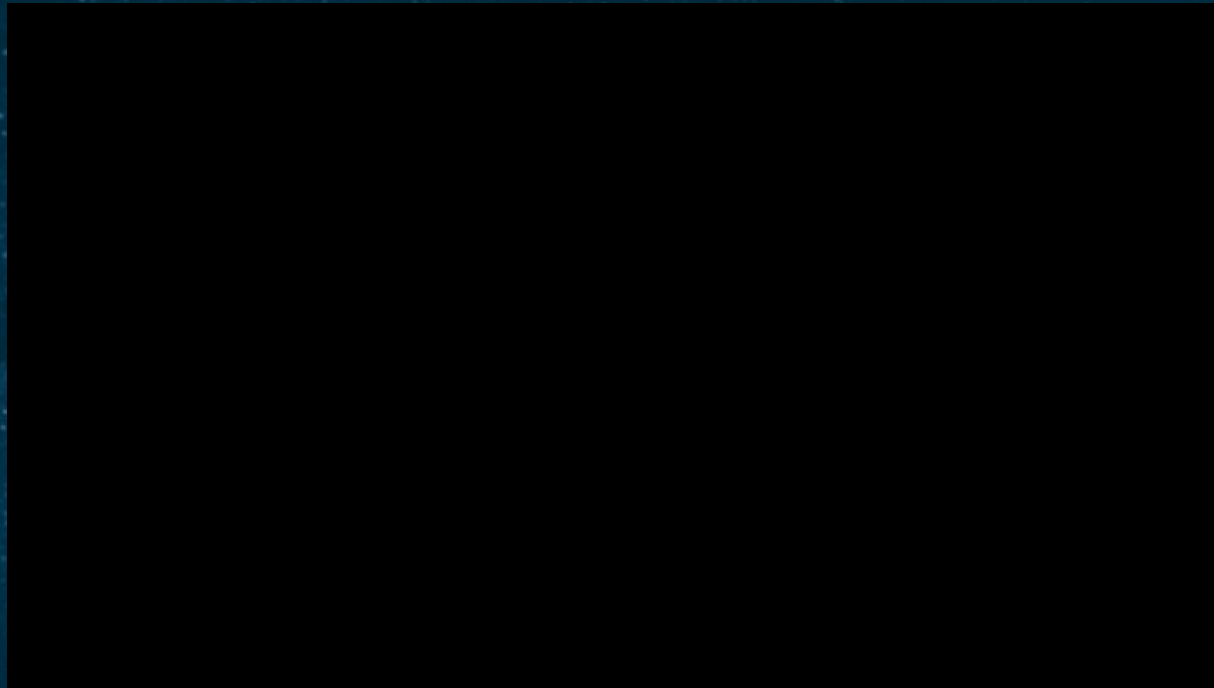


STEP 2: MOONLIGHT LCNS CONSTELLATION

High-data rate satellite communications and navigation service



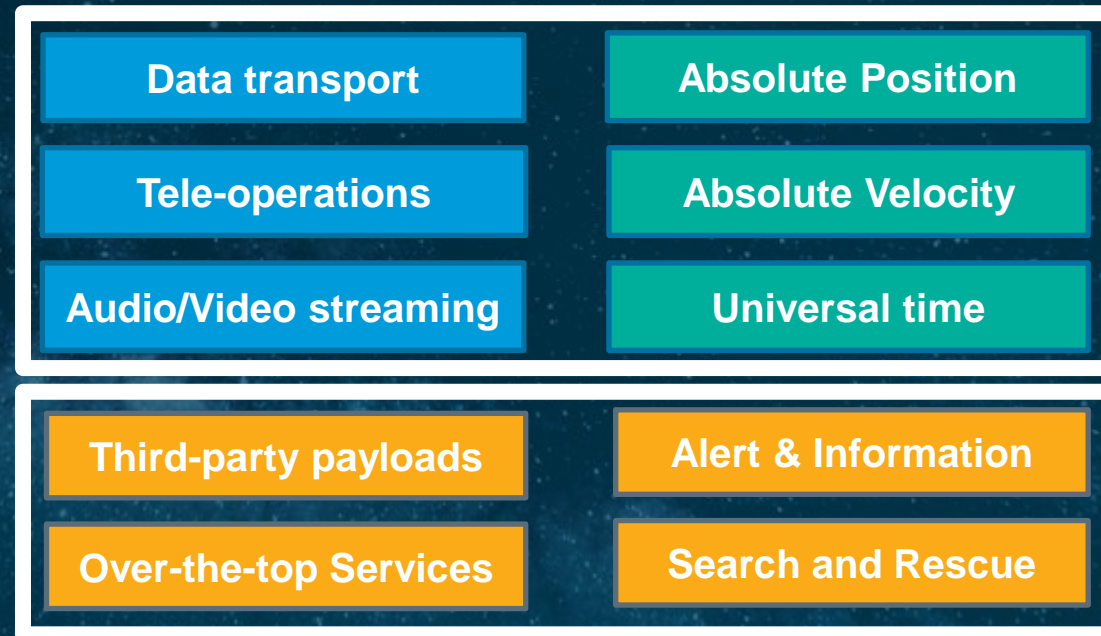
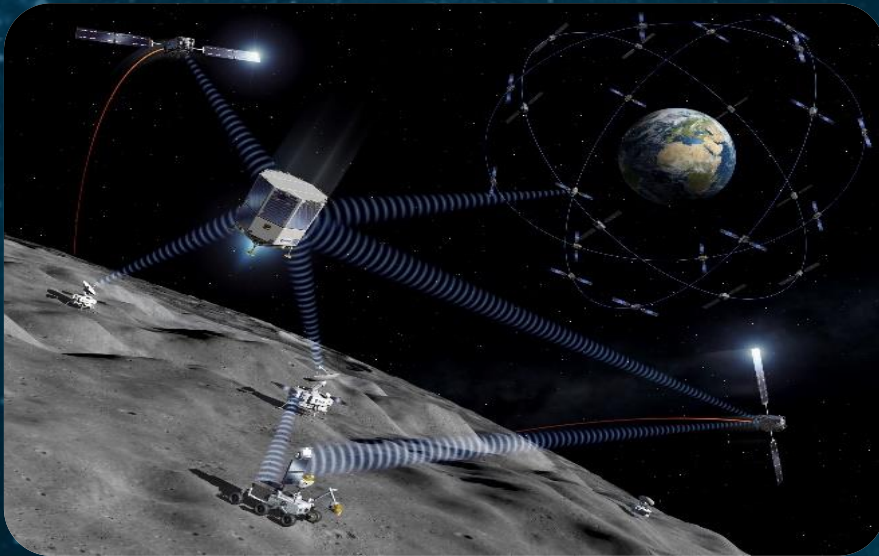
Moonlight Vision



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

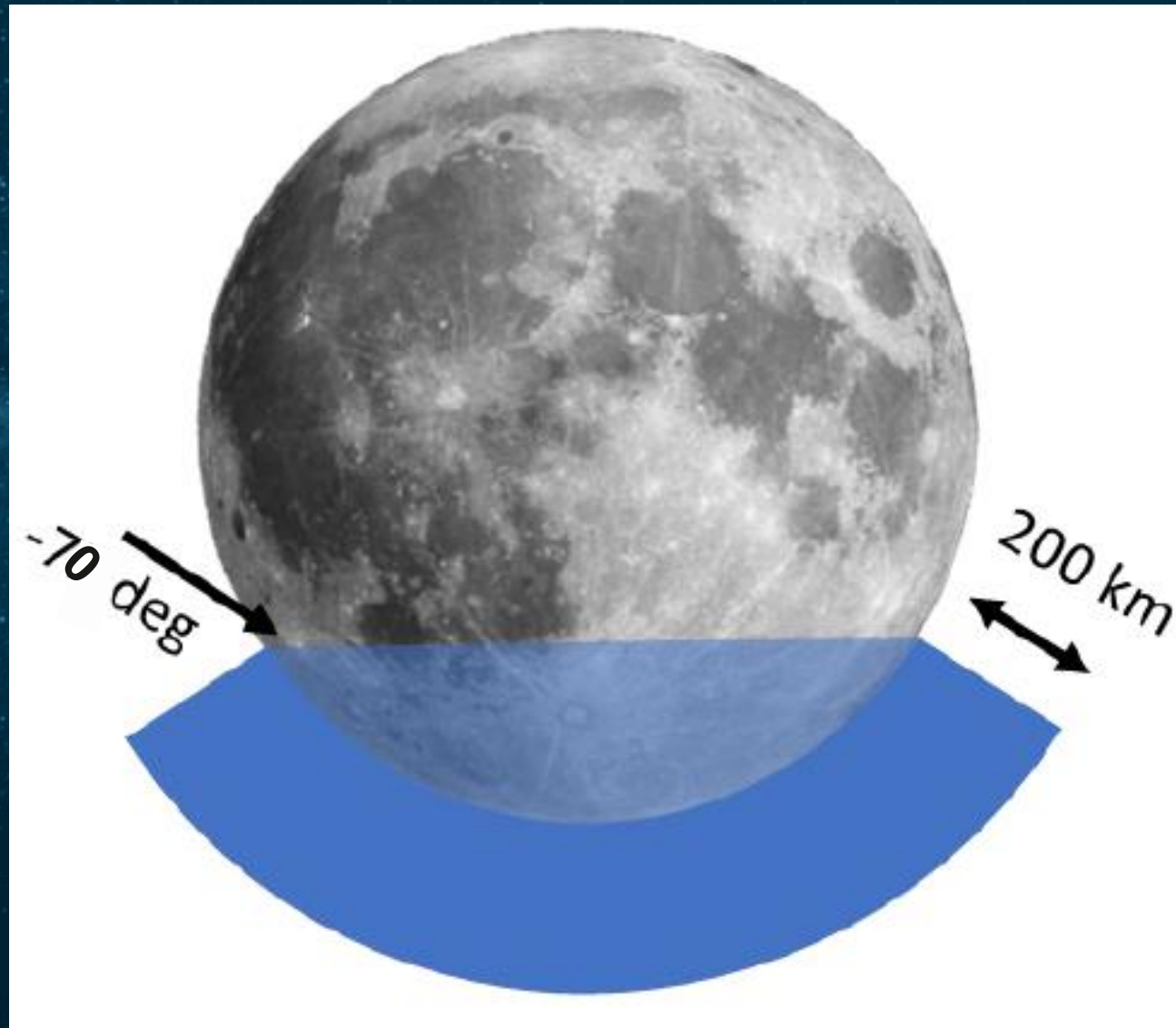
Moonlight Approach & Services

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

FOCUSING ON THE SOUTH POLE



Moonlight LCNS High-level Service Requirements



High DataRate (KBand)
Upto 200Mbps/user



Low Datarate (Sband)
Upto 1Mbps/user



Security functions



Slotted Real time services



Based on GNSS technologies



Precise timing (95%)
(100 ns)

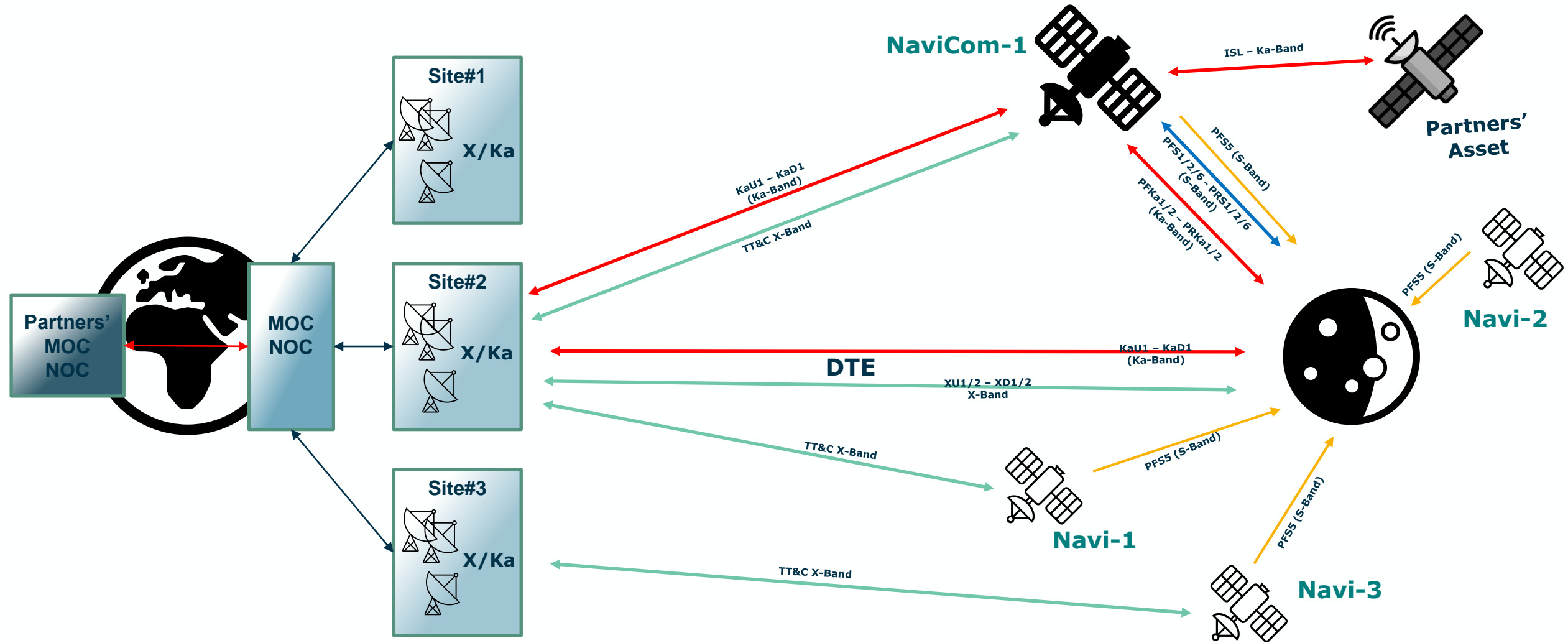


One Way Ranging
SISE ODTS (95%)
IOC: 20 m
FOC: 10 m



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

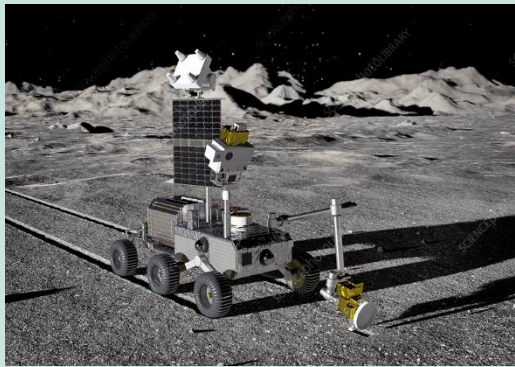
Moonlight: Mission Architectural Concept



Moonlight PNT services are at reach with proposed GNSS technologies !

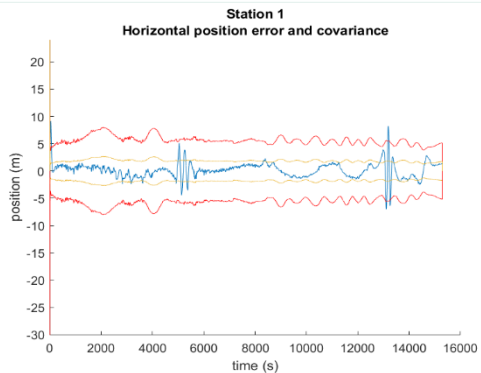
Extensive ESA and industrial simulations & analysis performed

Surface Rover



Real time
< 10 m (95%)

Post-processing
< 3 m (95%)



3-5 meters

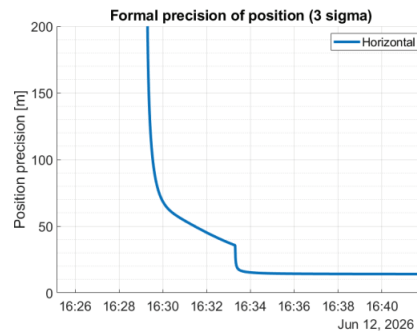
Ref: Navigation Performance of a Lunar Surface Rover Using LCNS Positioning Assuming Realistic ODTs Performances, **EUROPEAN NAVIGATION CONFERENCE 2023**

Lunar Lander



< 50 m (95%)

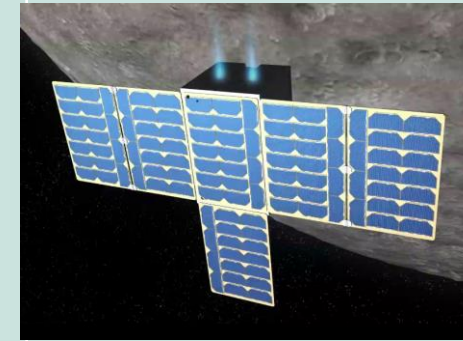
Landing accuracy



~20 meters

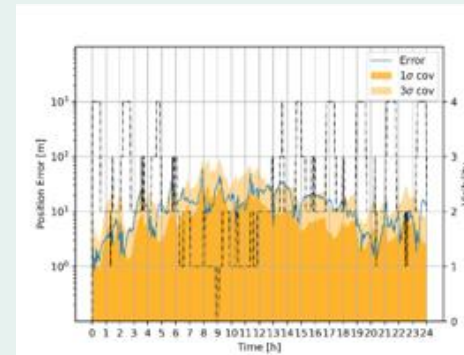
Ref: Positioning and Velocity Performance Levels for a Lunar Lander using a Dedicated Lunar Communication and Navigation System, **Navigation Journal 2022**

Lunar Orbiter



Real time
< 100 m (95%)

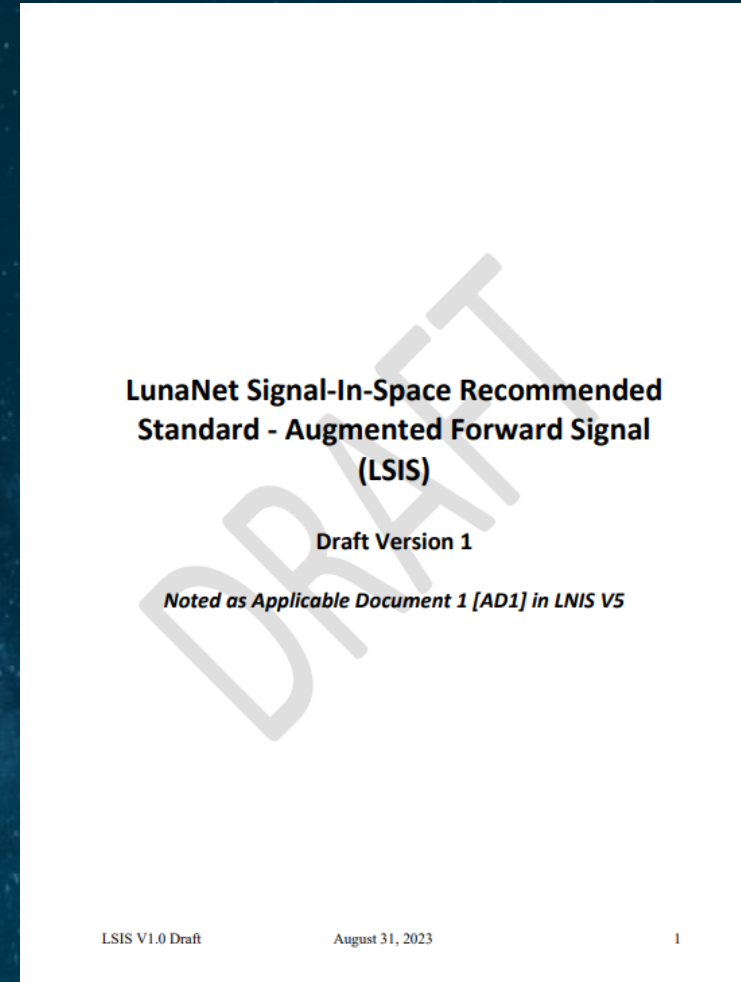
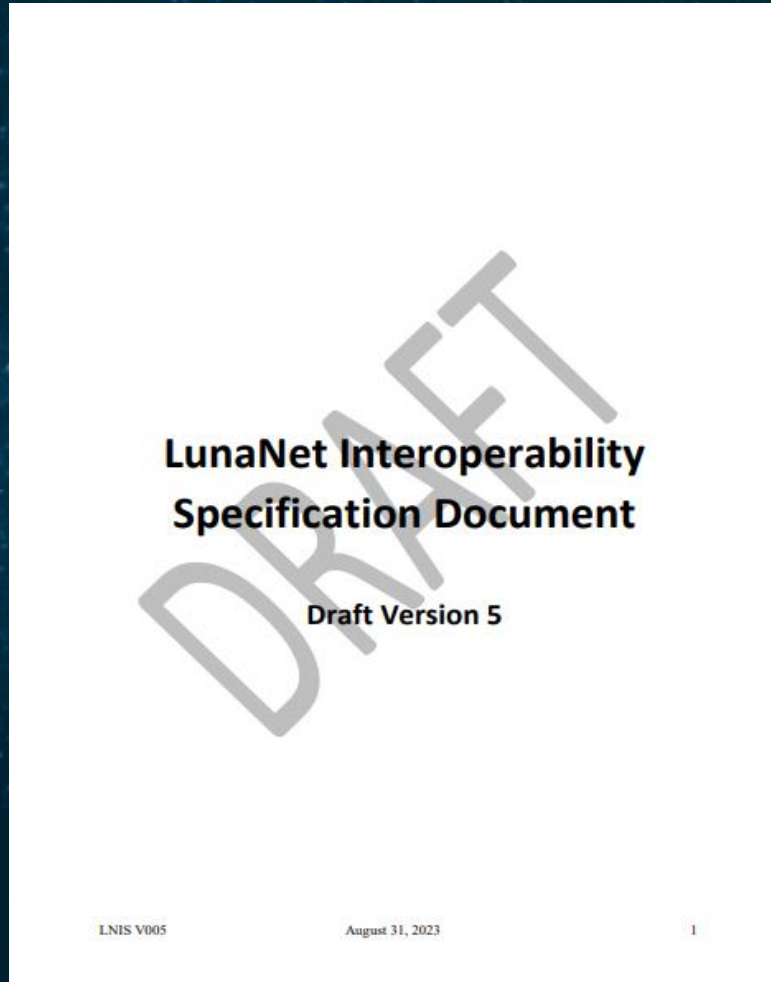
LLO accuracies



30-60 meters

Ref: Navigation performance of Low Lunar Orbit satellites using a Lunar Radio Navigation Satellite System, **ION-GNSS 2023**

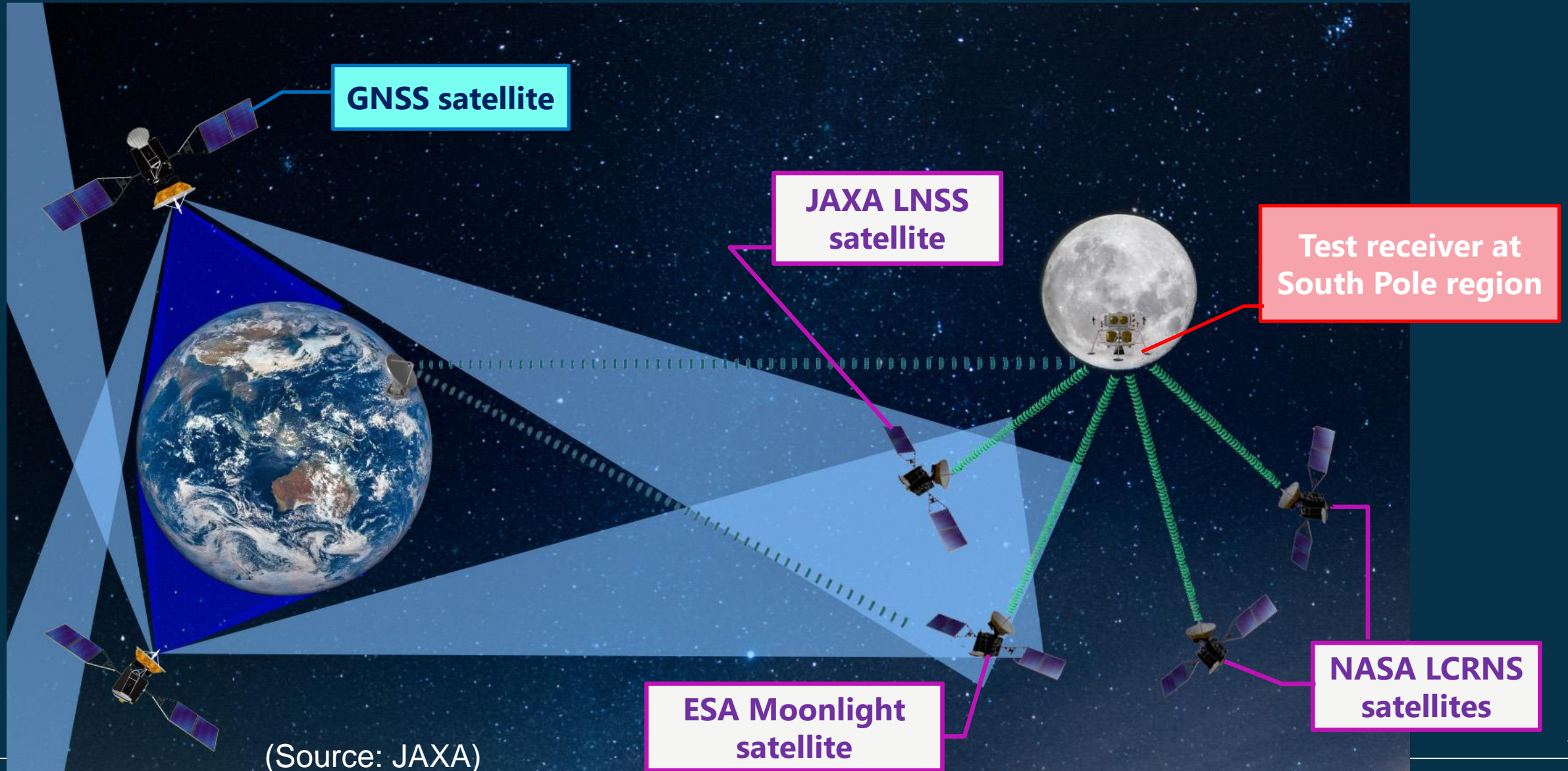
MOONLIGHT will be developed to comply with LunaNet Interoperability Specifications



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

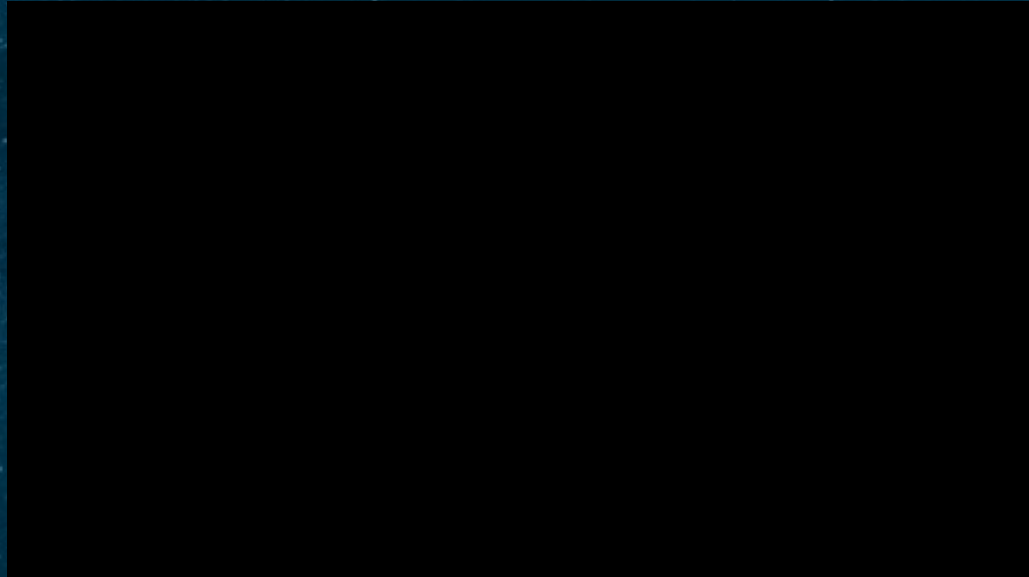


First-ever lunar PNT interoperability demonstration could take place in 2028 (under joint assessment by JAXA, ESA and NASA)





Moonlight VIDEO



Thank you!

