

ESA LUNAR NAVIGATION PLANS:

LUNAR PATHFINDER & MOONLIGHT



Dr Javier Ventura- Traveset
Head of Navigation Science Office
Moonlight-NAV Manager
European Space Agency



International Committee on
Global Navigation Satellite Systems



ESA UNCLASSIFIED – Releasable to the Public



We are going back to the Moon.....

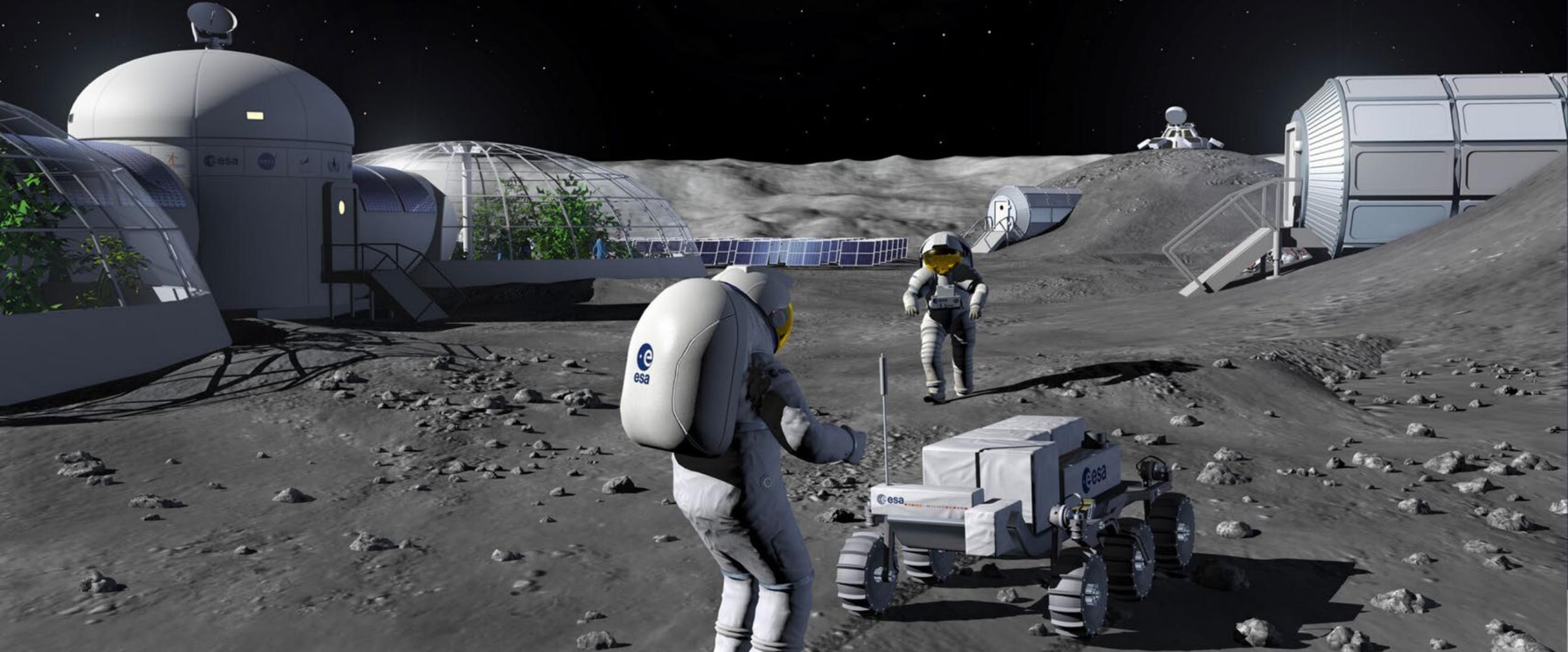


Credits: BBC Science Focus Magazine

... and stay there



Over 250 missions foreseen in lunar orbit or lunar surface for the next 10 years !!



A market prediction over 100 Billion Dollars

Moon Markets Analysis, 2nd Edition

NSR
NORTHERN SKY RESEARCH
An Analysis Mason Company

Key Markets Driving the Return to the Moon are **Science & Technology Development**, **Asset Transportation**, and **Pre-human Robotic Exploration** - Totalling

62%

Of the Entire Market Missions

The **251+** Missions Expected Over the Next 10 Years Will Activate the

100 Billion Moon Economy

\$100B

2021

Mission Launches Per Year

2031

■ Science&Tech ■ Transportation ■ Robotics ■ Manned

The Fundamental Building Blocks for the Moon Market Started with the Objective of Building a Sustainable Presence of Humans, However as we Dive Into the Early Years of the Missions - it is Clear that the Need for Science and Technology Development, Transportation of Payloads, and Transmitting Data and Communication Back to Earth is Becoming a Clear Winner in the Picture.

Northern Sky Research, One Mifflin Place, Suite 400, Cambridge, MA, 02138, 1-(617)-674-7743

NSR



Artemis: Landing Humans On the Moon



Lunar Reconnaissance Orbiter: Continued surface and landing site investigation



2022

Artemis I: First human spacecraft to the Moon in the 21st century



2024

Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st Century



2025

Gateway begins science operations with launch of Power and Propulsion Element and Habitation and Logistics Outpost



Artemis III-V: Deep space crew missions; cislunar buildup and initial crew demonstration landing with Human Landing System



Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers



Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey



Uncrewed HLS Demonstration

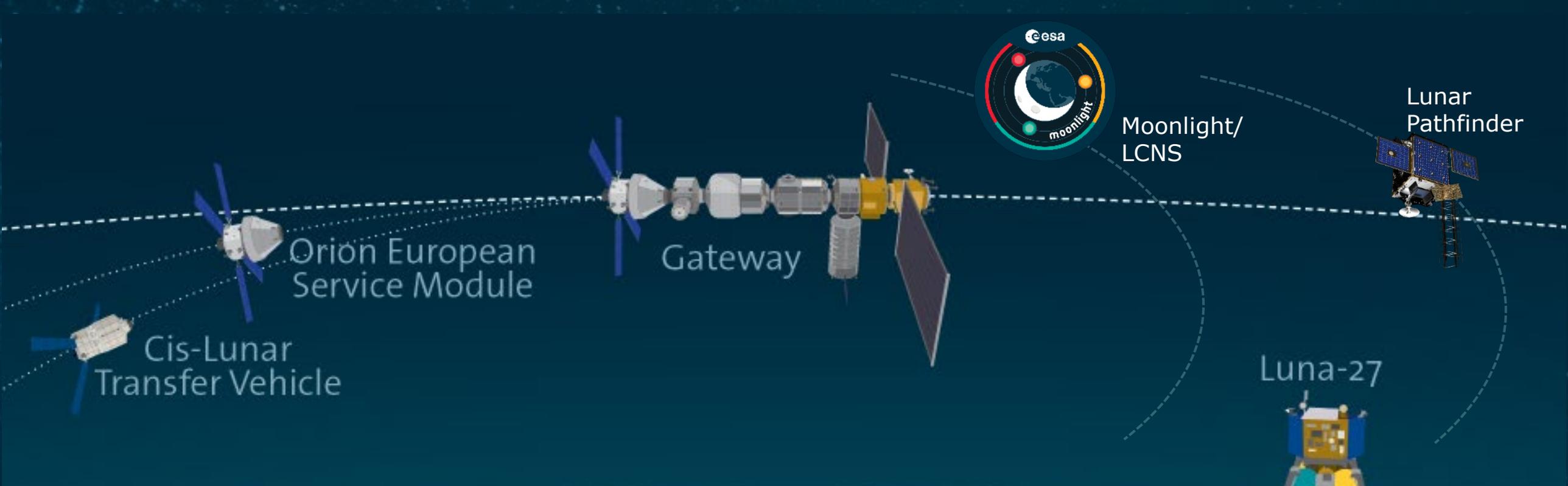


2025

Humans on the Moon - 21st Century
First crew expedition to the lunar surface



LUNAR SOUTH POLE TARGET SITE



Europe's main contributions to future lunar exploration

European Large Logistic Lander



The current model (each missions provide its means) is not cost effective

The 250+ missions planned already for next 10 years, **would require all their own Com & Nav provision means**

Opportunity to ignite new services **and contribute to sustainable Moon economy by providing a dedicated Lunar COMM and NAV infrastructure**

Commercial Lunar Payload Services

- CLPS-delivered science and technology payloads

Early South Pole Mission(s)

- First robotic landing on eventual human lunar return and In-Situ Resource Utilization (ISRU) site
- First ground truth of polar crater volatiles

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

ESA Roadmap plans for Lunar Navigation Services



Phase 1: Use of Existing Earth-GNSS Systems (2023 – onwards)	Phase 2: Moonlight NAV Initial Services (2027 – 2035)	Phase 3: Moonlight NAV enhanced services (2035 – onwards)
<p>Preliminary Lunar PNT services</p> <p>Earth-based GNSS (Galileo and GPS) using high-sensitive GNSS Receivers</p>	<p>Moonlight Lunar PNT services</p> <p>Dedicated initial lunar orbit GNSS-like constellation to provide South Pole surface and cislunar orbit services</p>	<p>Enhanced Moonlight Lunar PNT services</p> <p>Enhanced Lunar Comm and Nav Satellites constellation (with additional satellites and lunar surface PNT beacons) to provide Full lunar surface coverage and enhanced performances PNT performances</p>
<p>Lunar Pathfinder GNSS Payload IoD</p>	<p>MOONLIGHT / LCNS Initial Services</p>	<p>MOONLIGHT / LCNS: Enhanced Services</p>



STEP 1: LUNAR PATHFINDER

Low-rate satellite communications service + Moon GNSS Receiver

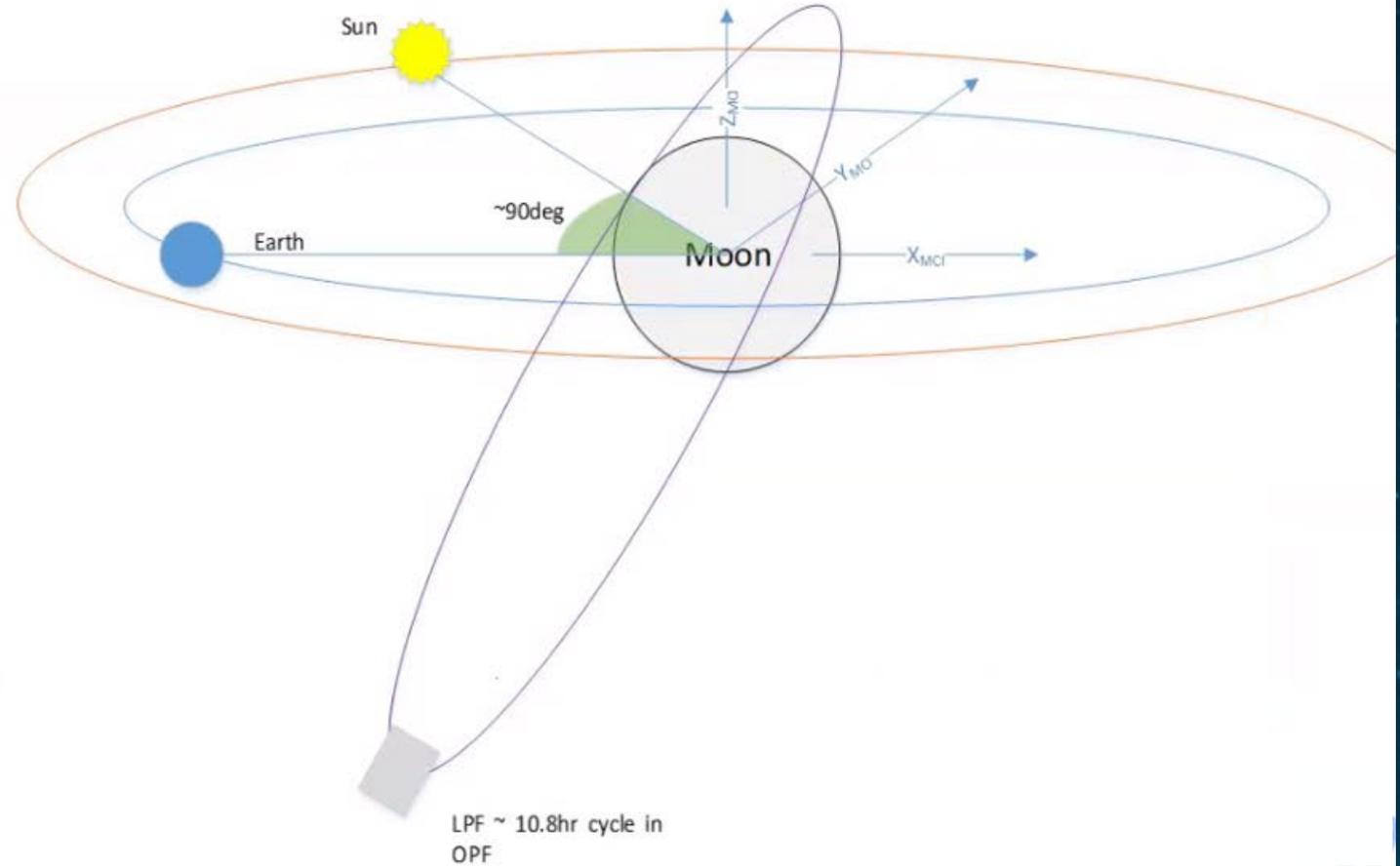
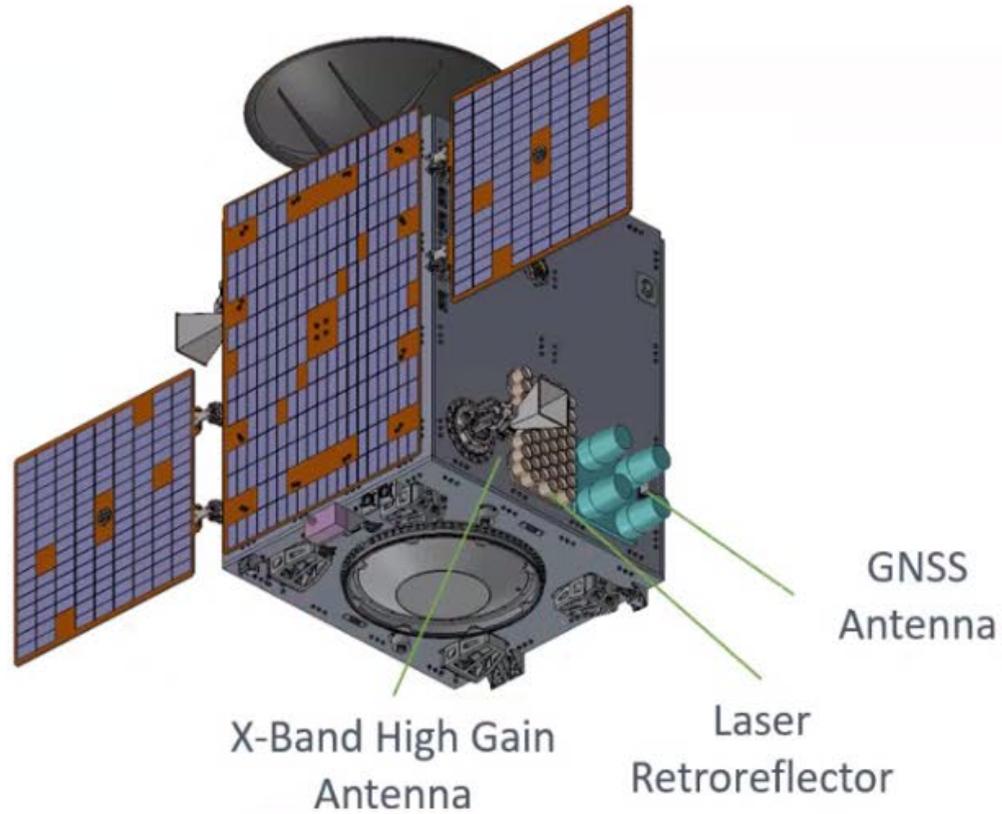


STEP 2: MOONLIGHT PROGRAMME

High-data rate satellite communications and navigation service



Lunar Pathfinder Satellite – First ever GPS/GALILEO reception on lunar orbit



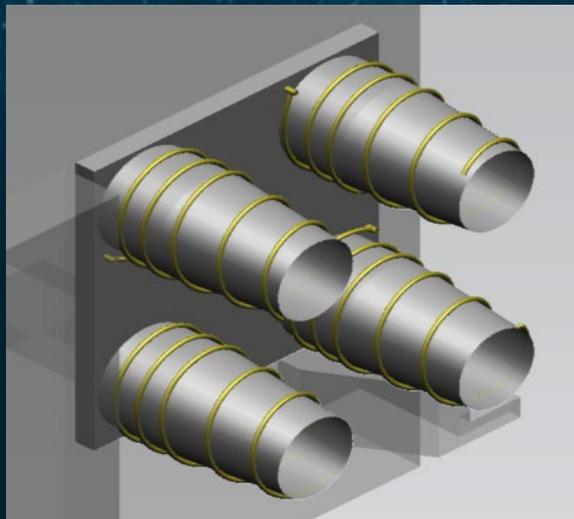
001 SSTI

Lunar Pathfinder equipped with GNSS high-sensitive receiver / GNSS high-gain antenna



Parameter	Value
Acquisition sensitivity	15dBHz
Tracking sensitivity	15dBHz
3D Position accuracy	< 100m RMS
3D Velocity accuracy	< 0.1 m/s RMS
Mass	1.3 Kg
Size	24x12x7cm
Power	< 12W
Constellations	GPS / Galileo L1/E1/L5/E5

SpacePNT NaviMoon Receiver Specifications



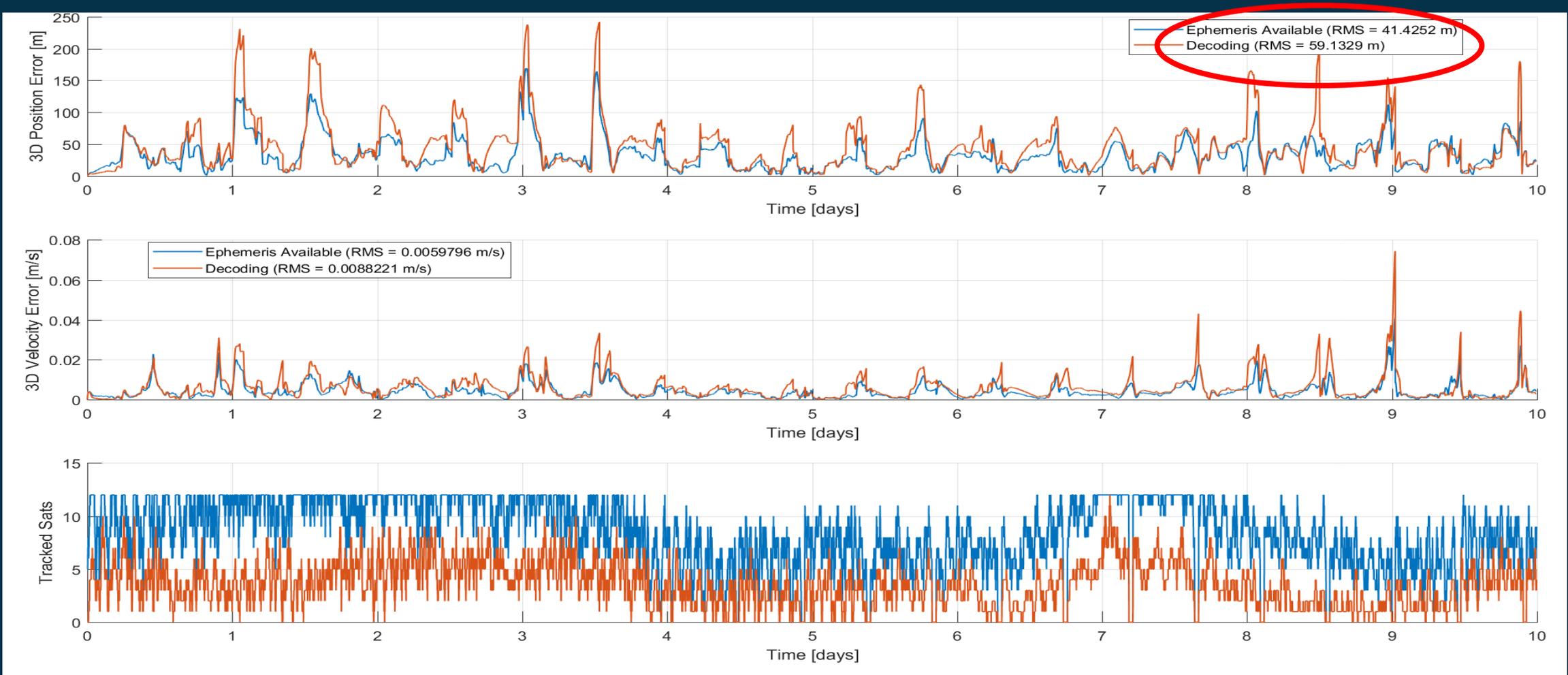
Parameter	Value
L1 boresight gain	15 dBi
L5 boresight gain	12 dBi
Polarization	RHCP
Mass	~2Kg
Size	26x26x28cm

MDA Antenna Specifications

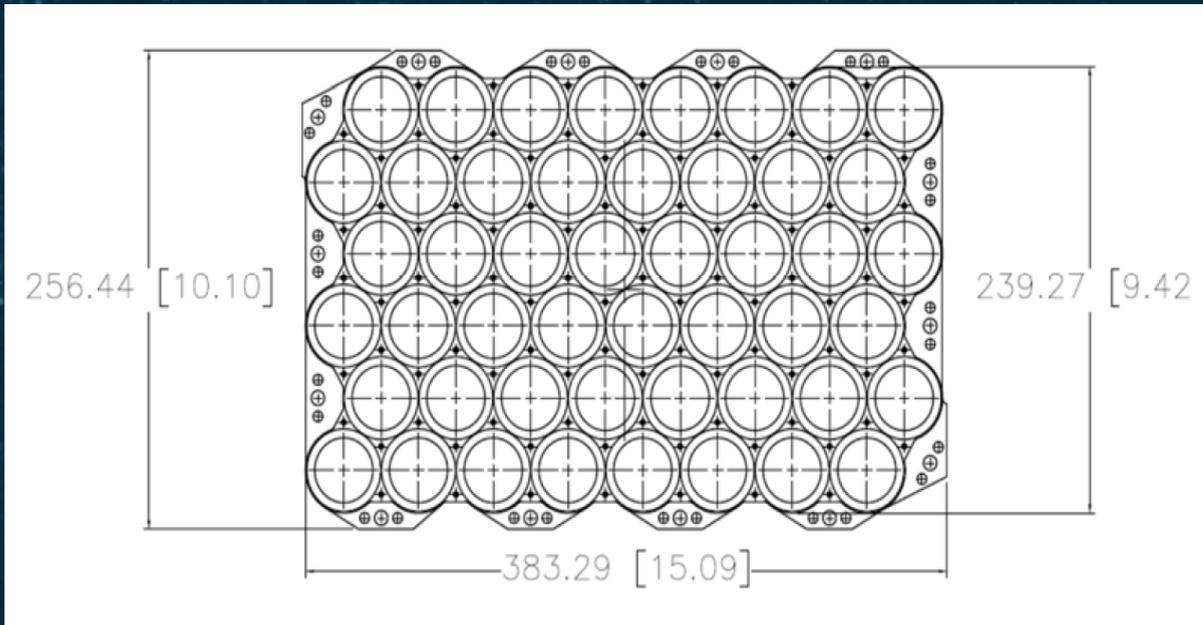
First ever demonstration of GNSS reception on Lunar orbit.



High-fidelity simulation performed with existing GNSS Receiver for Lunar Pathfinder: 10 days simulation

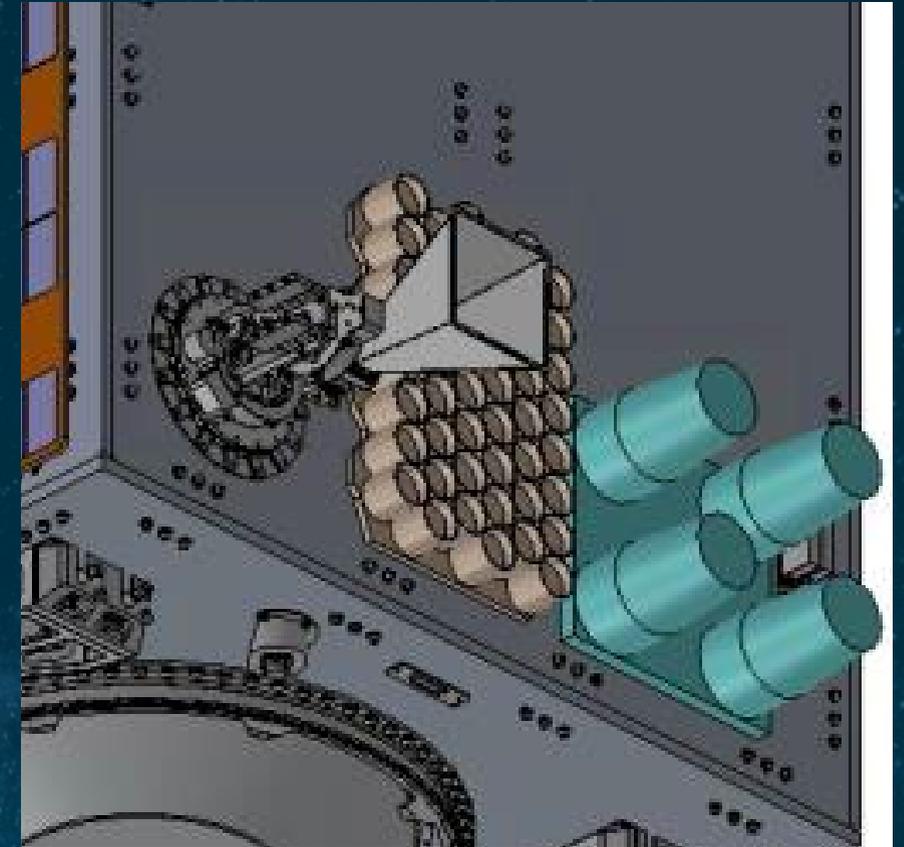


**Estimated autonomous and real time
Orbit Position accuracy ~ 50 meters (rms)**



Technical Description:

- LRR is composed of 48 reflector cubes (1.6" diameter), based on the technology developed and flown by NASA on the Lunar Reconnaissance Orbiter (LRO) - Mass ~ 4 kg



First time ever three ranging techniques (GNSS, Laser and X-band ranging) are used simultaneously on lunar orbit



STEP 1: LUNAR PATHFINDER

Low-rate satellite communications service + Moon GNSS Receiver



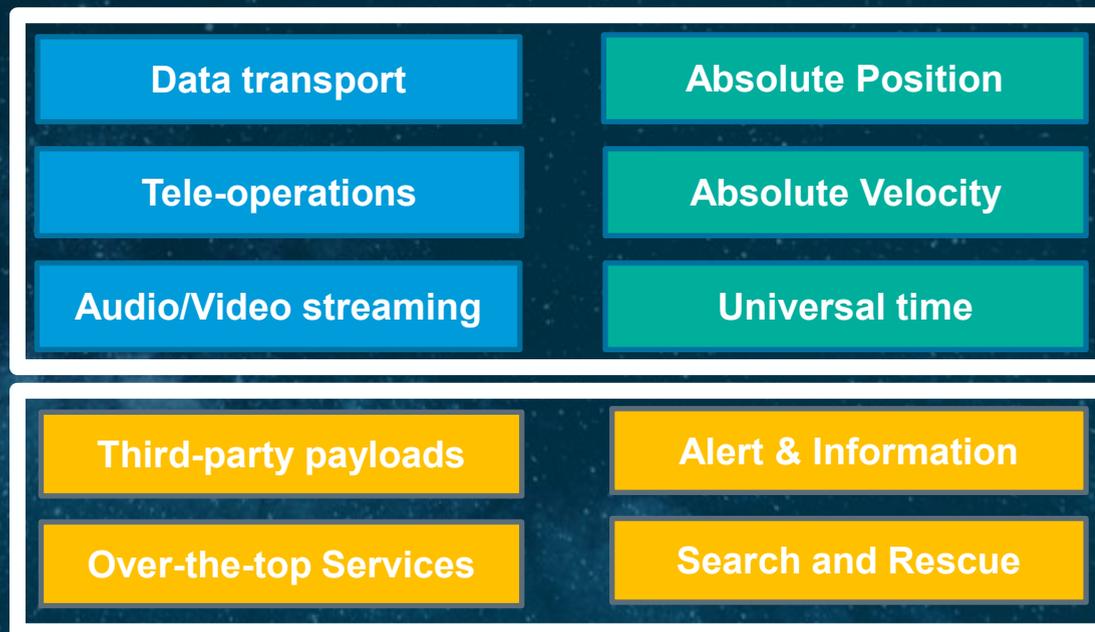
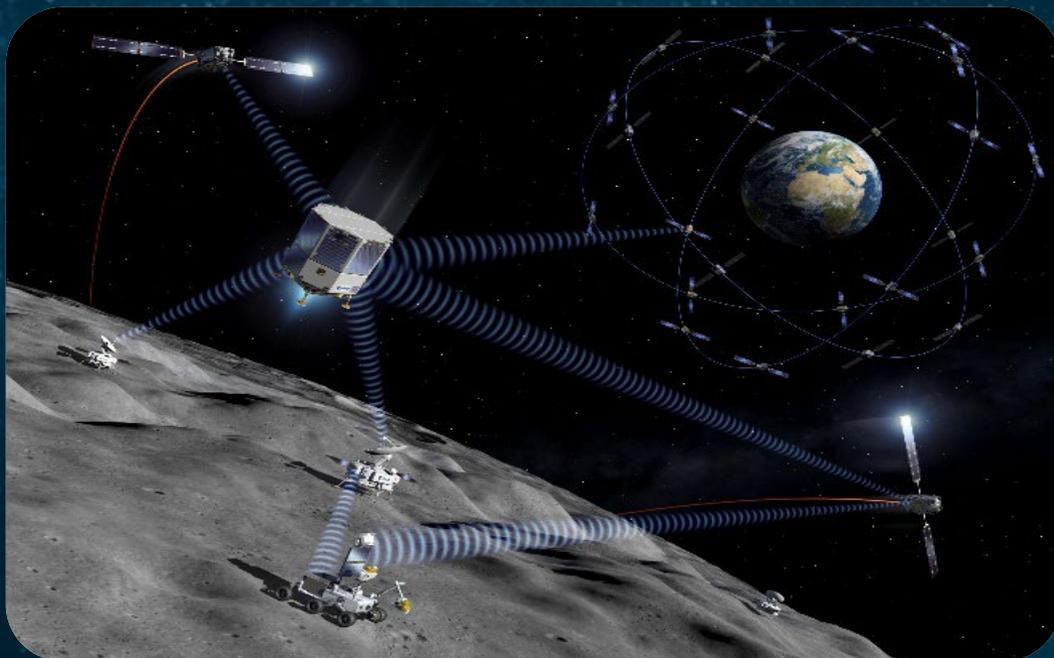
STEP 2: MOONLIGHT CONSTELLATION

High-data rate satellite communications and navigation service



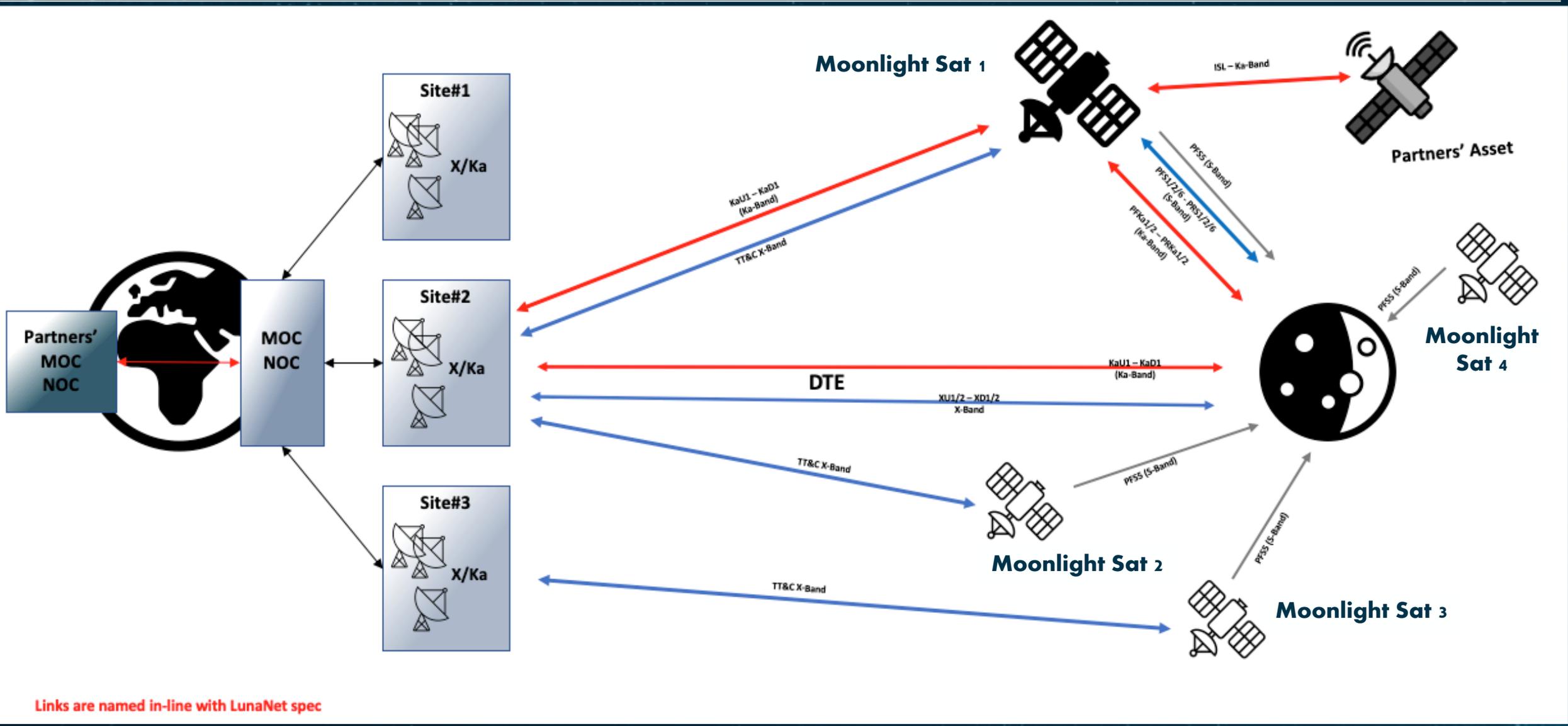
Moonlight Approach: Services

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



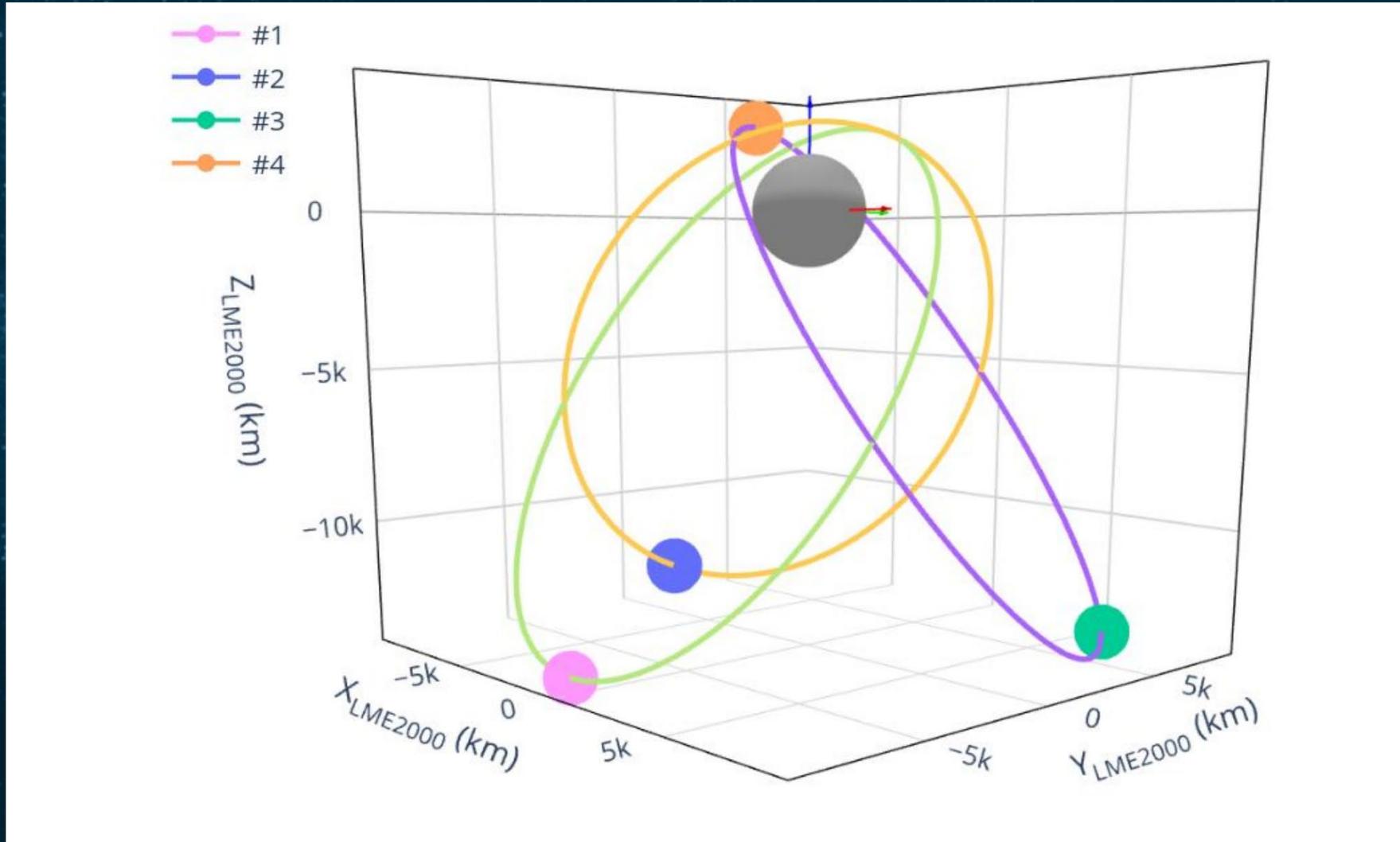
- A dedicated constellation of satellites around the Moon
- Moonlight NAV services based on GNSS technologies

Moonlight LCNS – Example System Concept

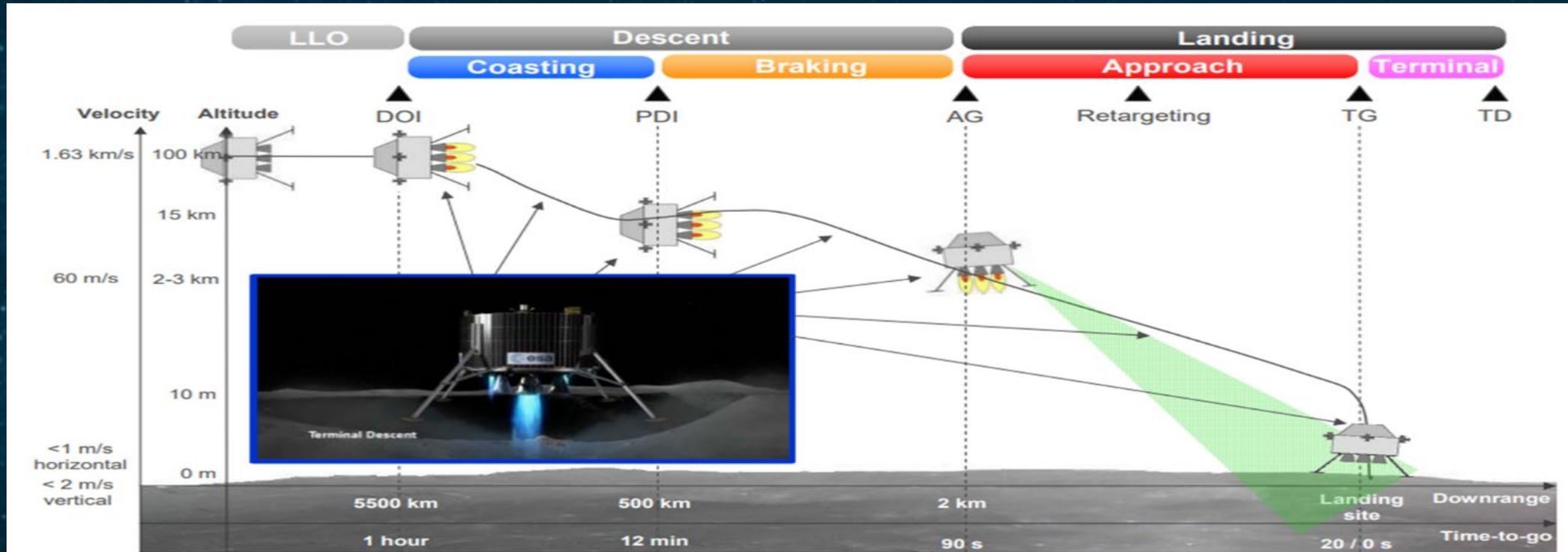


Links are named in-line with LunaNet spec

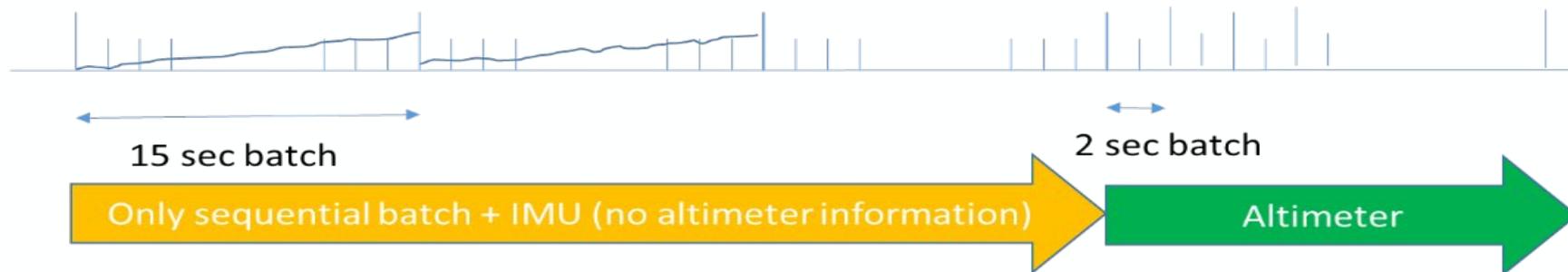
4 satellites initial constellation: ELFO ORBITS



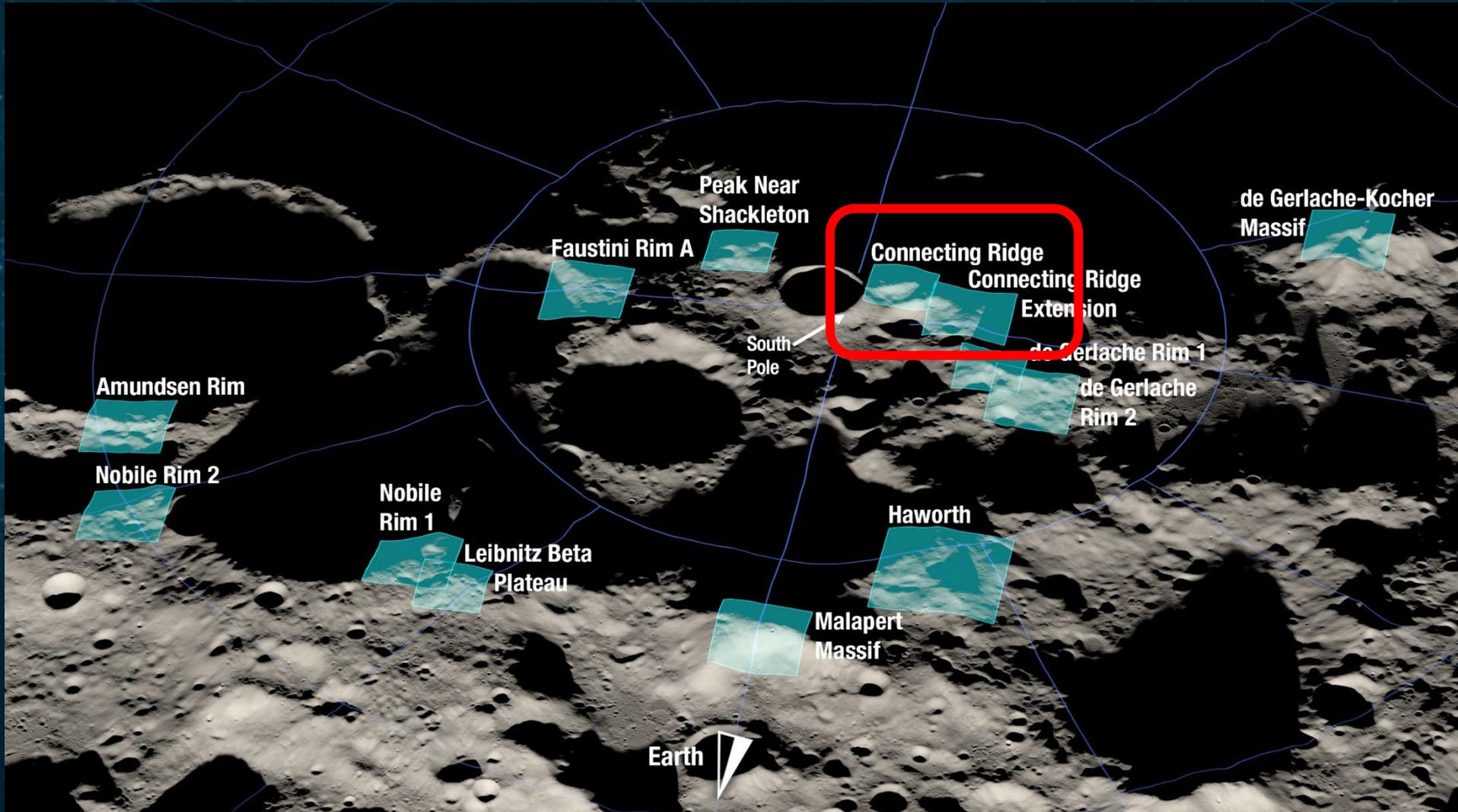
Example of Moonlight Service Capabilities: Moon landing



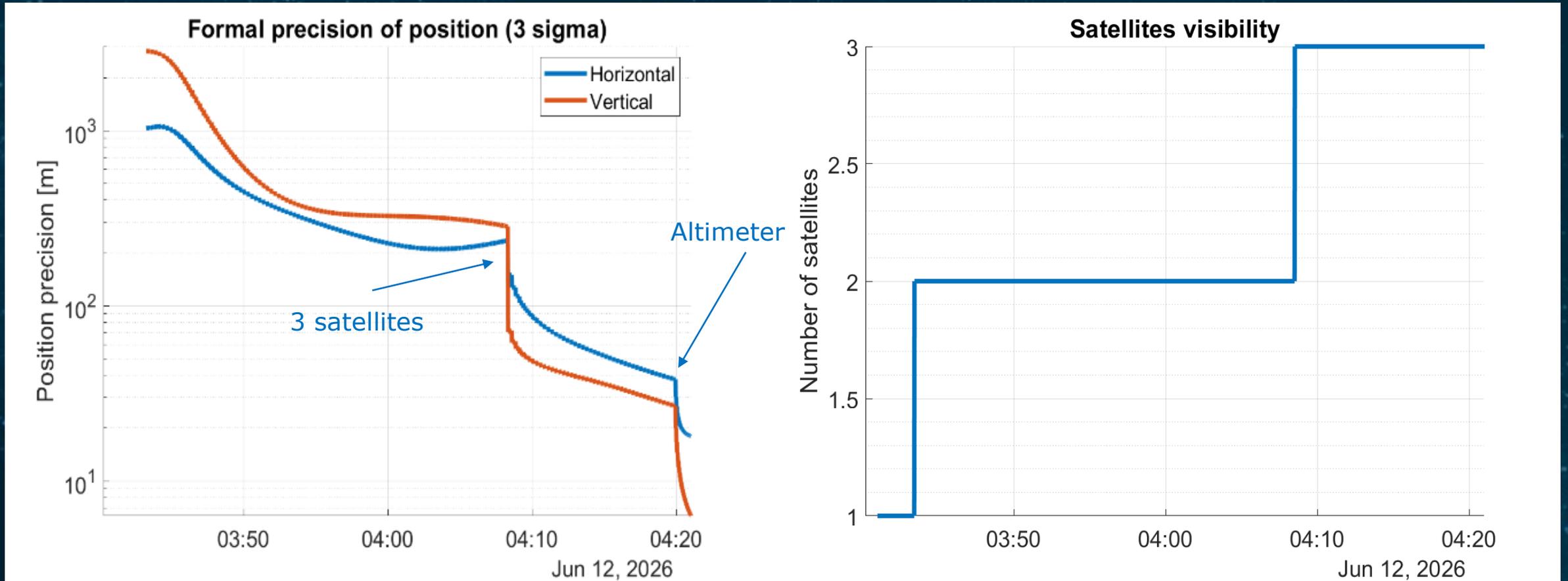
Note: the velocity, altitude, downrange, delta-V and time values are provided to give an order of magnitude



Lunar Landing locations proposed for Artemis

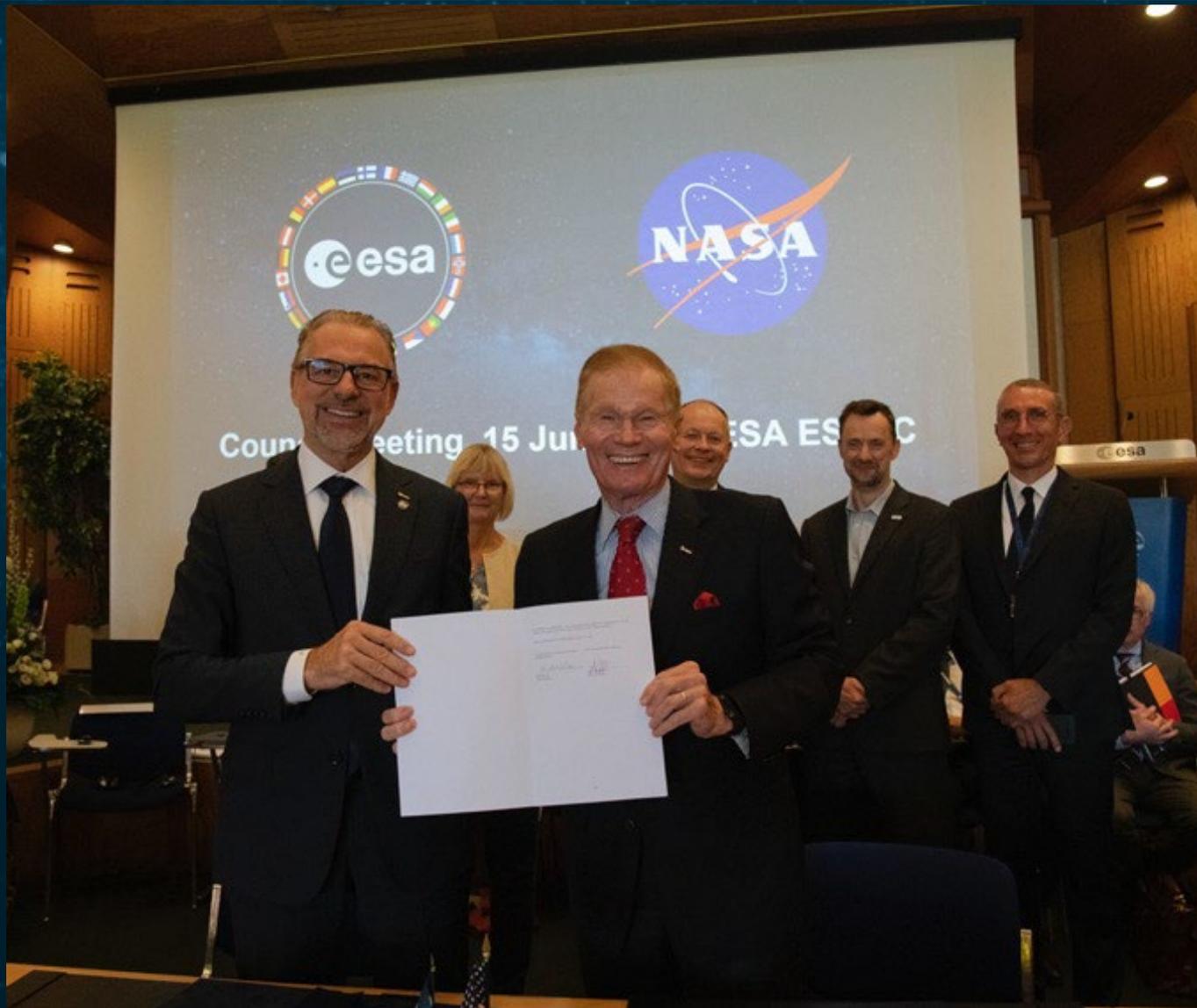


Moonlight estimated achievable Landing performances



The achieved final landing horizontal precision is below 20 m 3-sigma !!

MOONLIGHT : A key assets in the cooperation of Europe in lunar exploration with NASA



Signature of MoU on Lunar Pathfinder – key stepping stone towards broader ESA NASA cooperation on lunar communication and navigation services (June 2022)

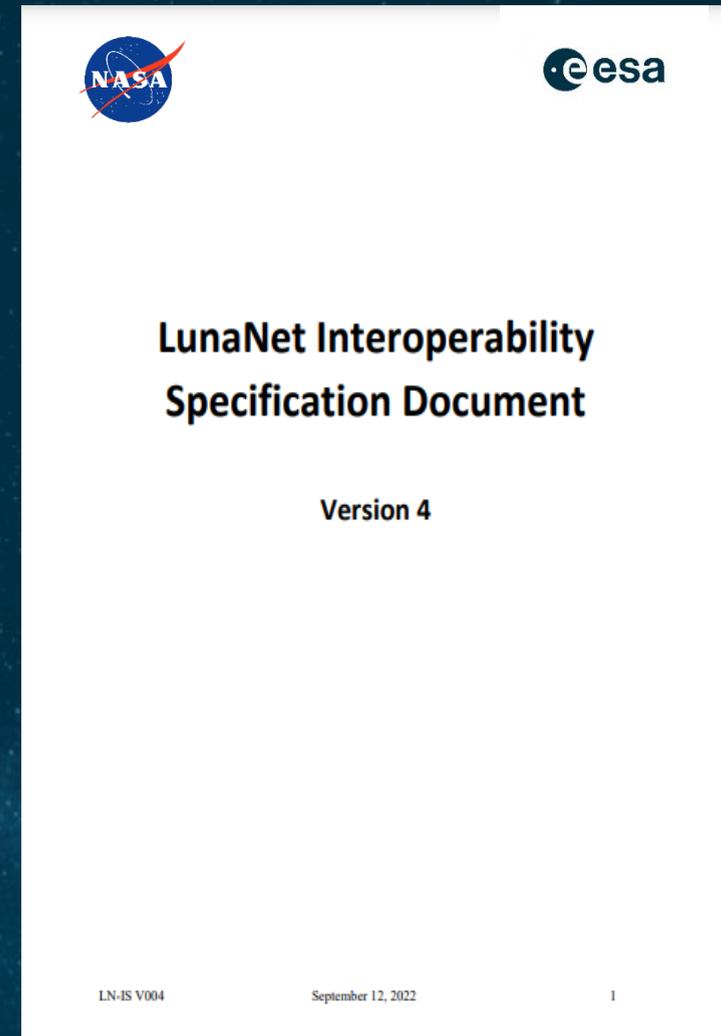
Moonlight is identified as one of 3 priority areas on future lunar surface cooperation between ESA and NASA onto the Artemis programme.

A dedicated Joint Understanding is being prepared and planned to be signed this fall and a formal ESA -NASA cooperation agreement is planned to be concluded in 2023.

MOONLIGHT TECHNICAL INTEROPERABILITY



- ESA is working closely with NASA on the definition of the joint lunar Communication and Navigation international standards
- High level of consensus achieved and convergence with NASA. Public version just released (Sept 2022) and cooperation started with IOAG.
- Maturity of the standards allow to proceed on the Moonlight implementation phase with low risk.
- Compliance to these Standards ensures technical compatibility with NASA Artemis missions and for joint use with NASA complementary infrastructure.



Technical Cooperation Moonlight/LunaNet

BILATERAL COOPERATION STARTED WITH JAXA



Discussions are on-going with JAXA

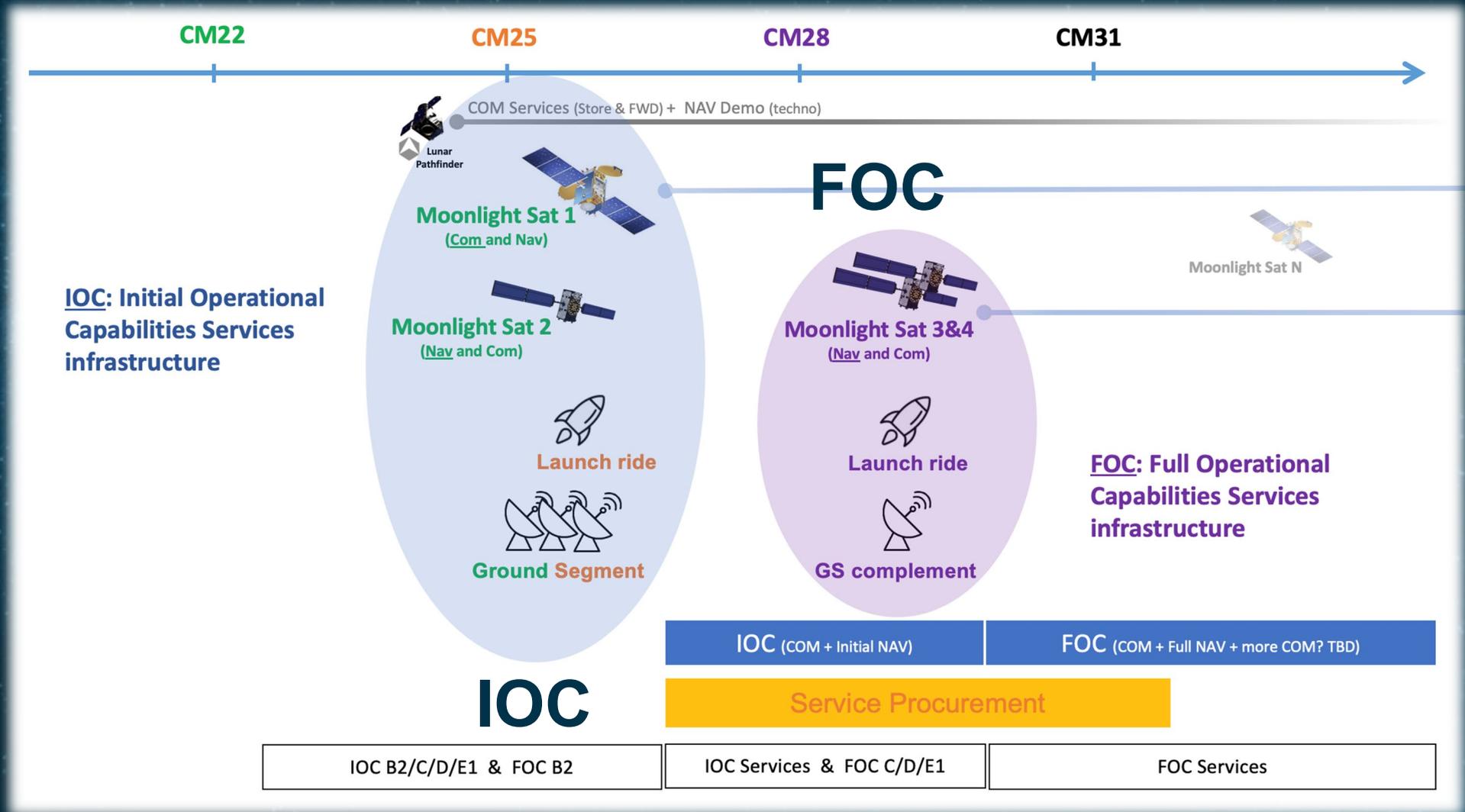
- ✓ Comparing assessment of lunar planned mission needs
- ✓ Assessing Systems Interoperability needs
- ✓ Potential cooperation on NAV technology demonstration (2028)
- ✓ Analysis of scenarios for joint service augmentation

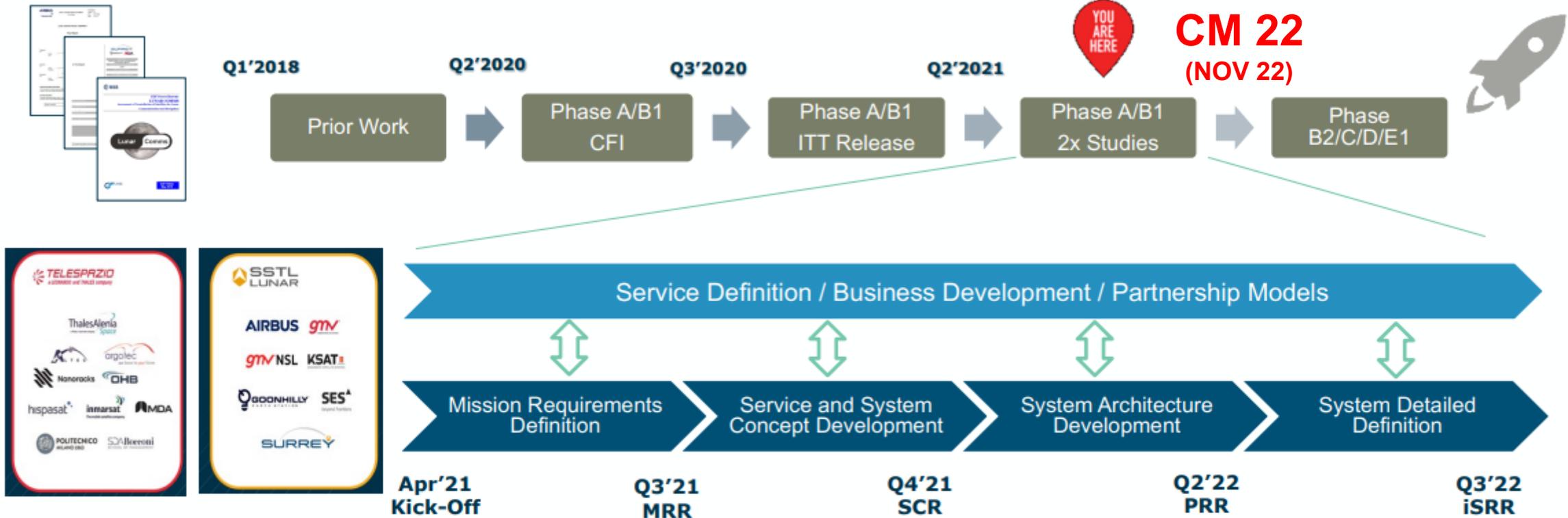


Moonlight LCNS system – Incremental deployment



IOC / FOC Approach





1. ESA has issued a Request For Information preparing for CM 2022 ~ Sept 2022
2. Moonlight ESA Ministerial endorsement expected in Nov 2022, allowing Full Moonlight Implementation (Phase B2/C/D/E)

Moonlight – LCNS Phase A/B1 Study consortia



Preparing for ESA Ministerial 2022: MOONLIGHT Request For Information



CAMPAIGN

Request for Information (RFI) for the Moonlight
programme preparation of the ESA Ministerial Council
of Nov 2022

Strategic Innovation Area: Telecommunications



ideas.esa.int

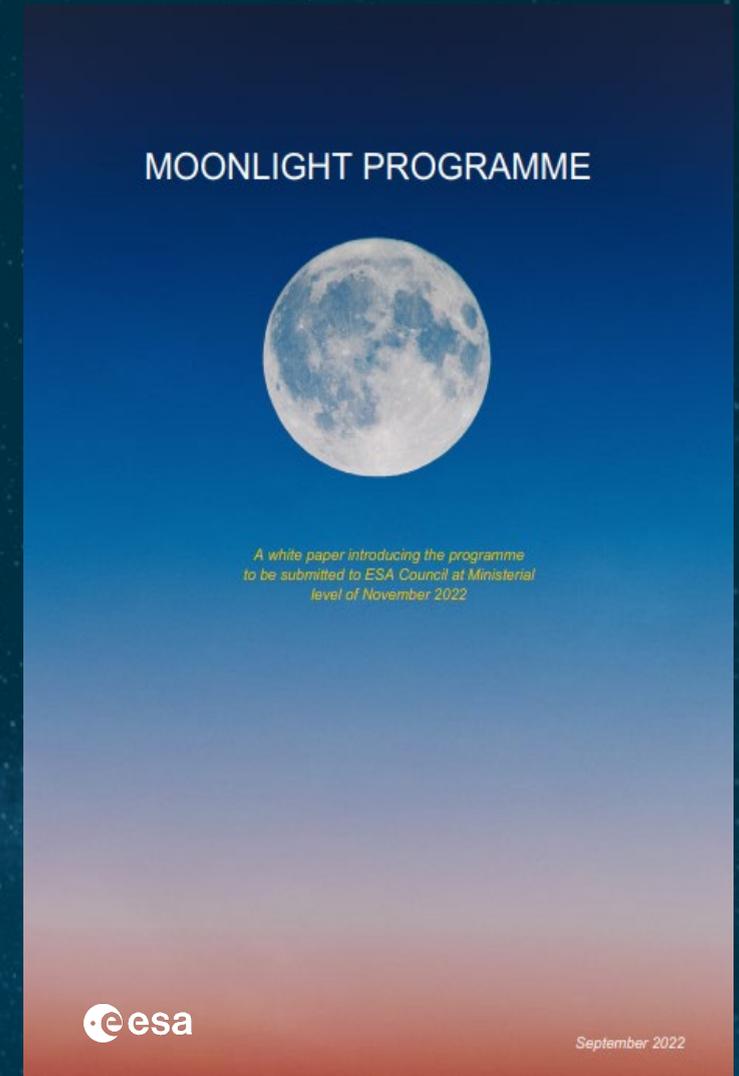
ESA Information provided:

- Draft Moonlight Service requirements
- A description of the Moonlight programme activities and execution



ESA has produced a “***Moonlight White paper***” summarizing the Objectives, organization and strategic importance of the Moonlight program, as presented for the ESA Ministerial Conference CM 22

https://esamultimedia.esa.int/docs/telecom/22.09.26_Moonlight_White_Paper.pdf





THANK YOU !

moonlight@esa.int