inValuable Lunar-Based Interferometry enabled by ESA's NovaMoon mission

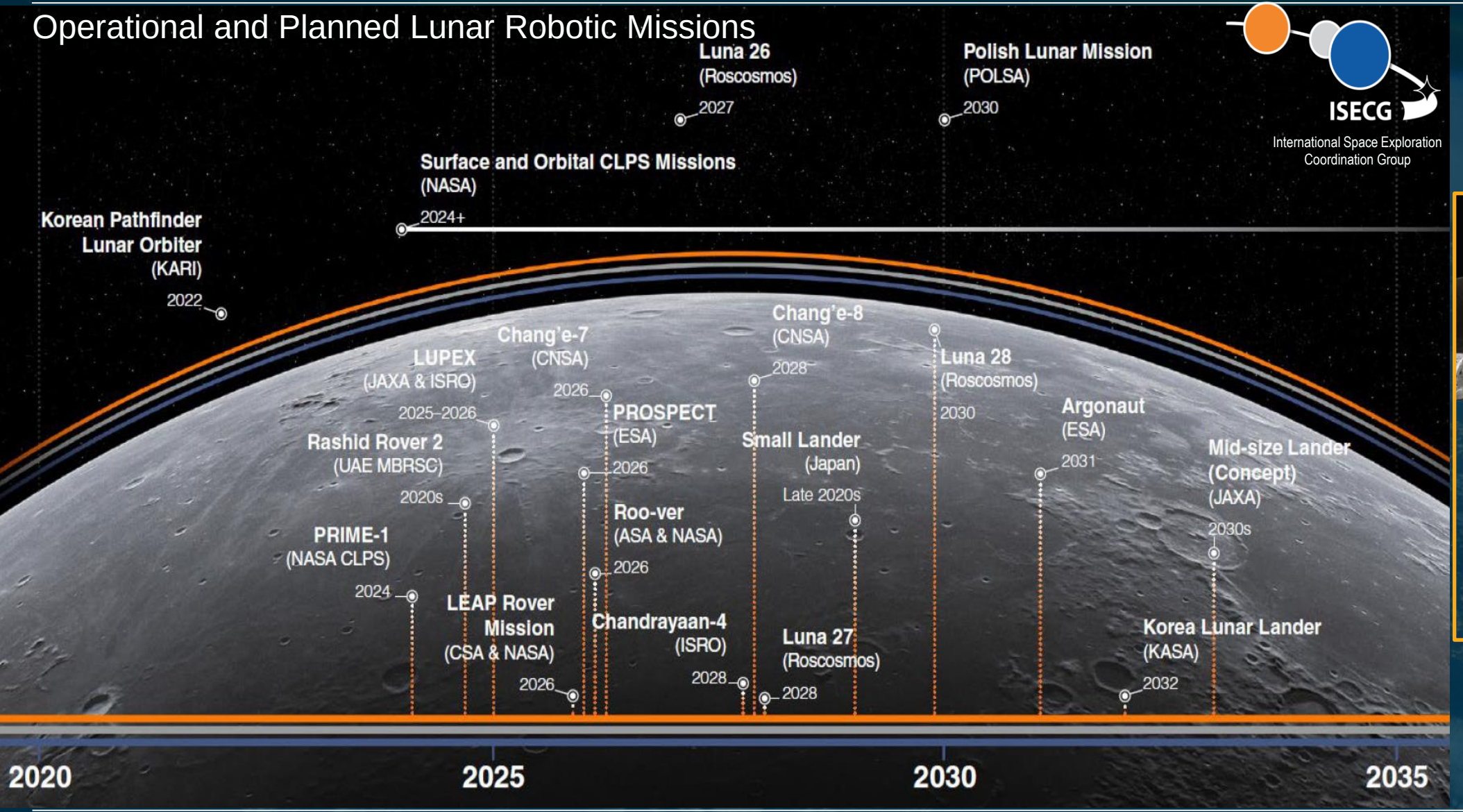
Sara Bruni[1], Serena Molli[2], Francesco Gini[2], Erik Schönemann[2], Richard Swinden[3], Yoann Audet[4], Floor Thomas Melman[5], Dimitrios Psychas[3], Javier Ventura-Traveset[6]

1. PosiTim UG for ESA/ESOC, Darmstadt, Germany
2. ESA/ESOC, Darmstadt, Germany
3. ESA/ESTEC, Noordwijk, The Netherlands
4. Telespazio Belgium SRL for ESA/ESTEC, Noordwijk, The Netherlands
5. Serco Netherlands B.V. for ESA/ESTEC, Noordwijk, The Netherlands
6. ESA/CST, Toulouse, France

EVGA Meeting ~ Matera, 07/04/2025

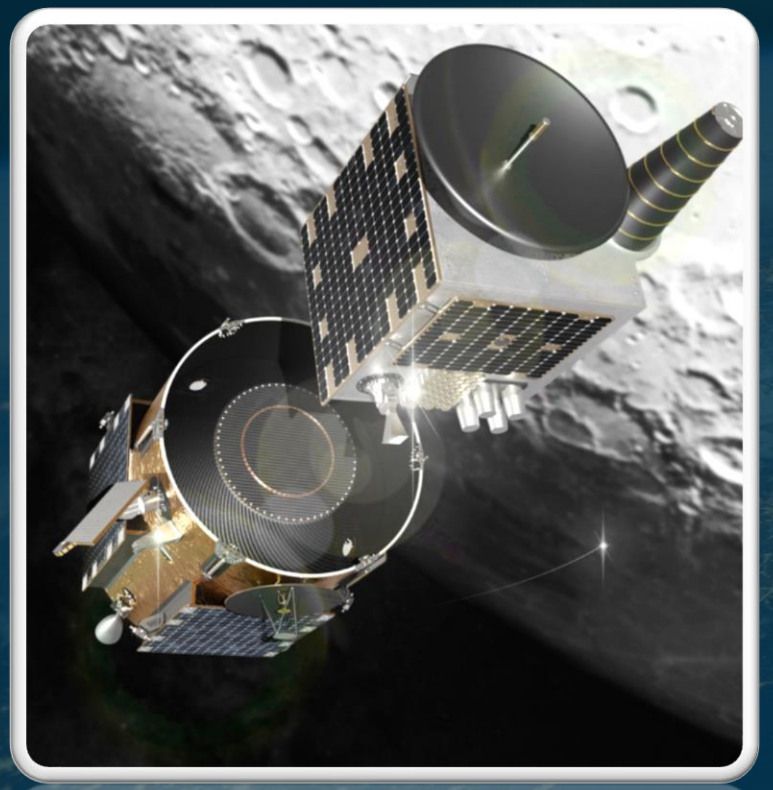
Why do we need lunar COMM and PNT Services?

Operational and Planned Lunar Robotic Missions



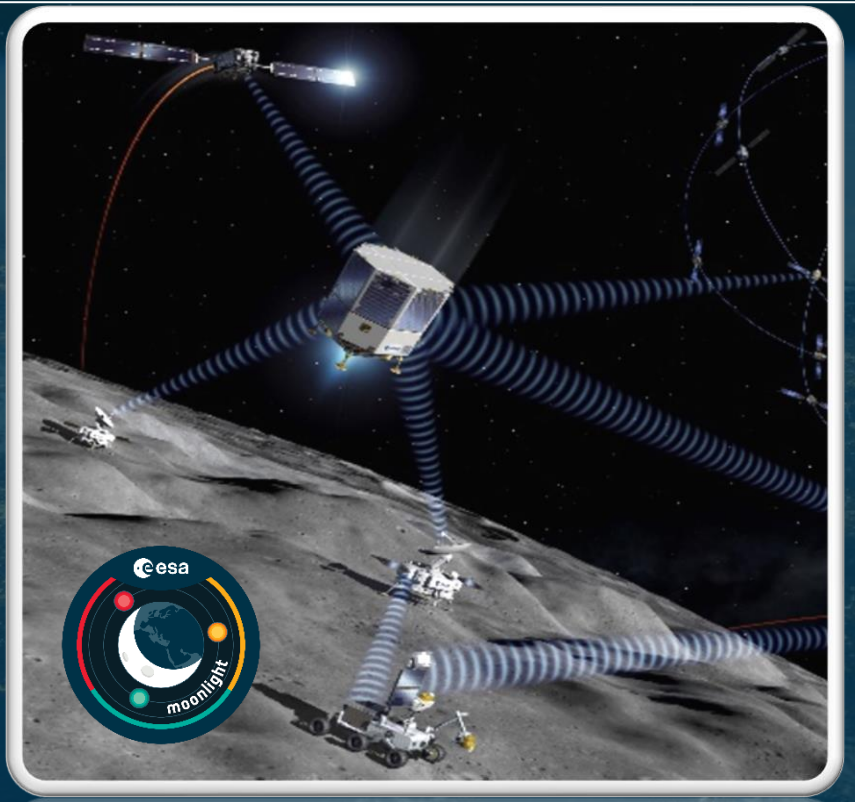
Roadmap to Boots on the Moon and Sustained Lunar Opportunities

ESA's Roadmap For Lunar COMM and PNT Services



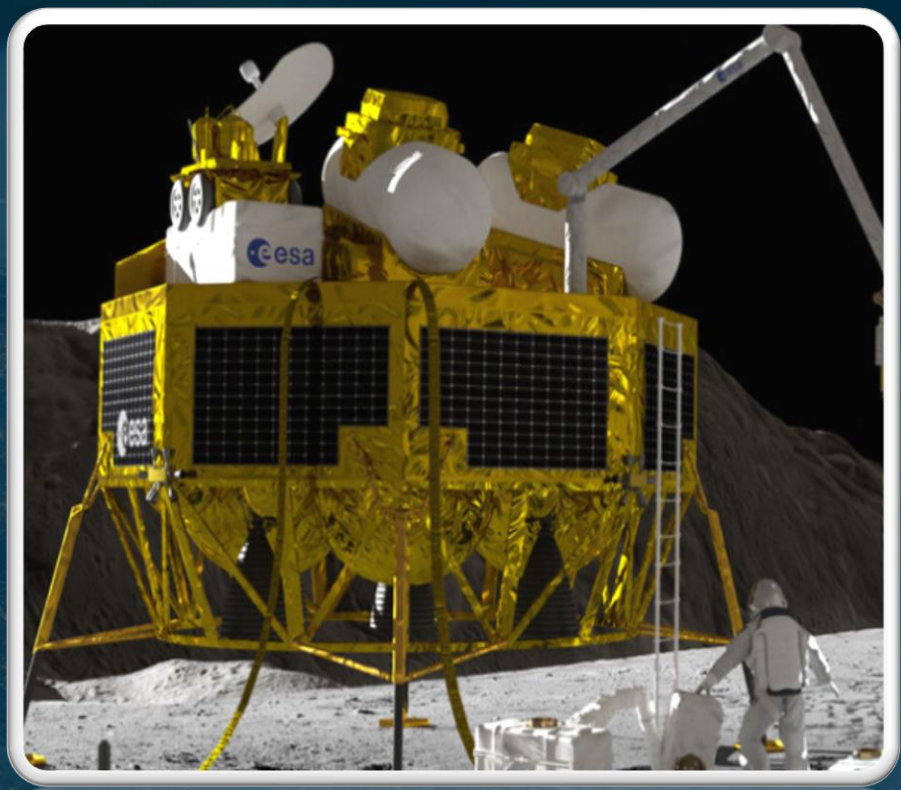
STEP 1:
LUNAR PATHFINDER

LAUNCH in 2026



STEP 2:
MOONLIGHT System

Phased deployment
2028-2030



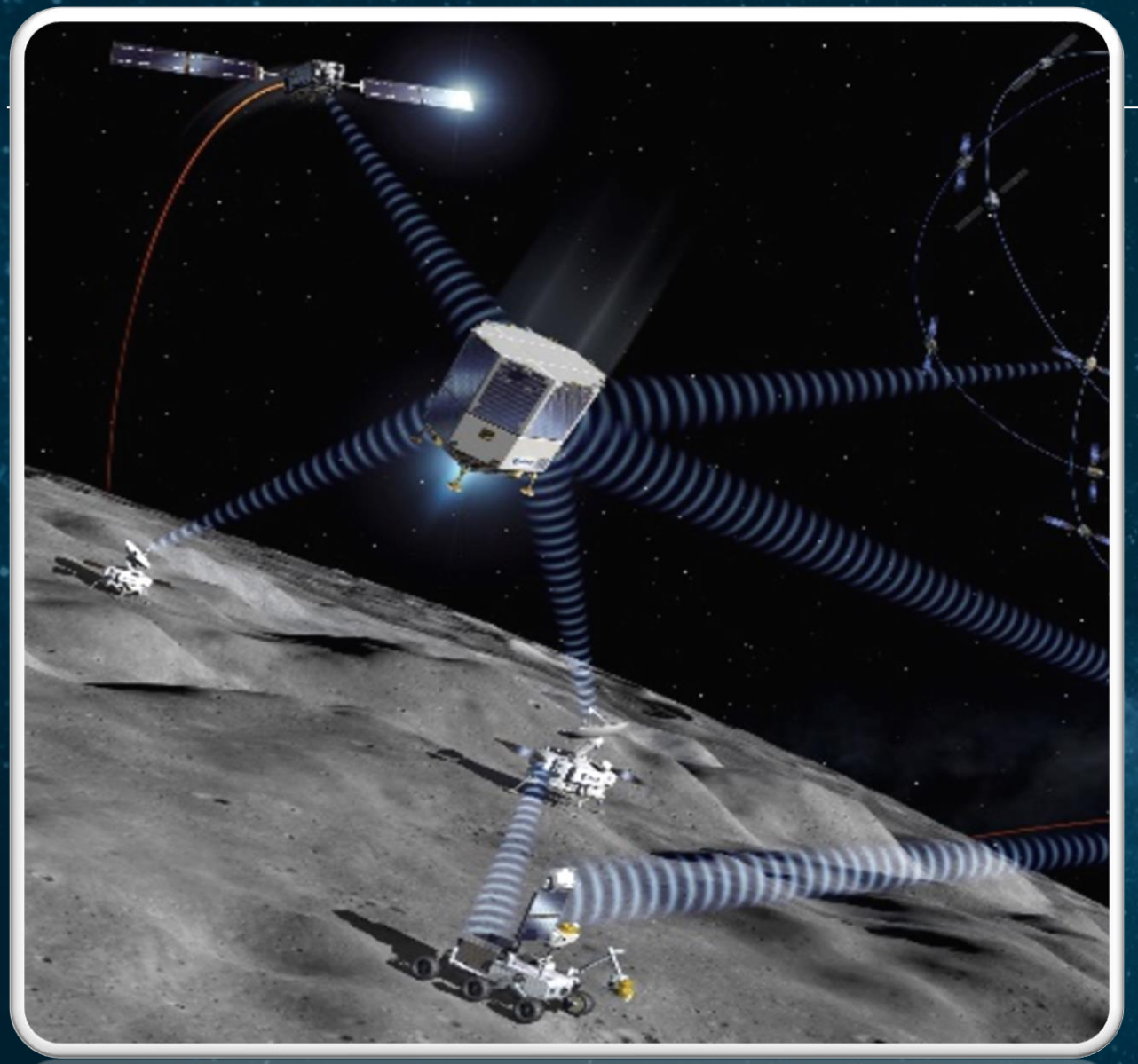
STEP 3:
NOVAMOON: Local PNT Differential Station
Launch: 2031
(subject to approval)

STEP 1: LUNAR PATHFINDER

- **Commercial Lunar Communication Relay Satellite**
- Public-Private Partnership (PPP) between ESA and Surrey Satellite Technology Limited (SSTL- UK)
- Will provide data relay operation for the first US lander on the far side (LuSEE-Night)
- **Launch:** Q2 2026 with FireFly's Blue Ghost CLPS-CS3
- **8 years lifetime**

It will host a high-sensitive GNSS receiver and a LLR retroreflector

STEP 2: Moonlight System



- A dedicated constellation of satellites around the Moon providing lunar communication and navigation services
- Partnership between ESA and a European consortia led by Telespazio Italy

Data transport	Absolute Position
Tele-operations	Absolute Velocity
Audio/Video streaming	Universal time

Moonlight LCNS High-level Mission and Service Drivers

Supporting Commercial & Institutional Missions

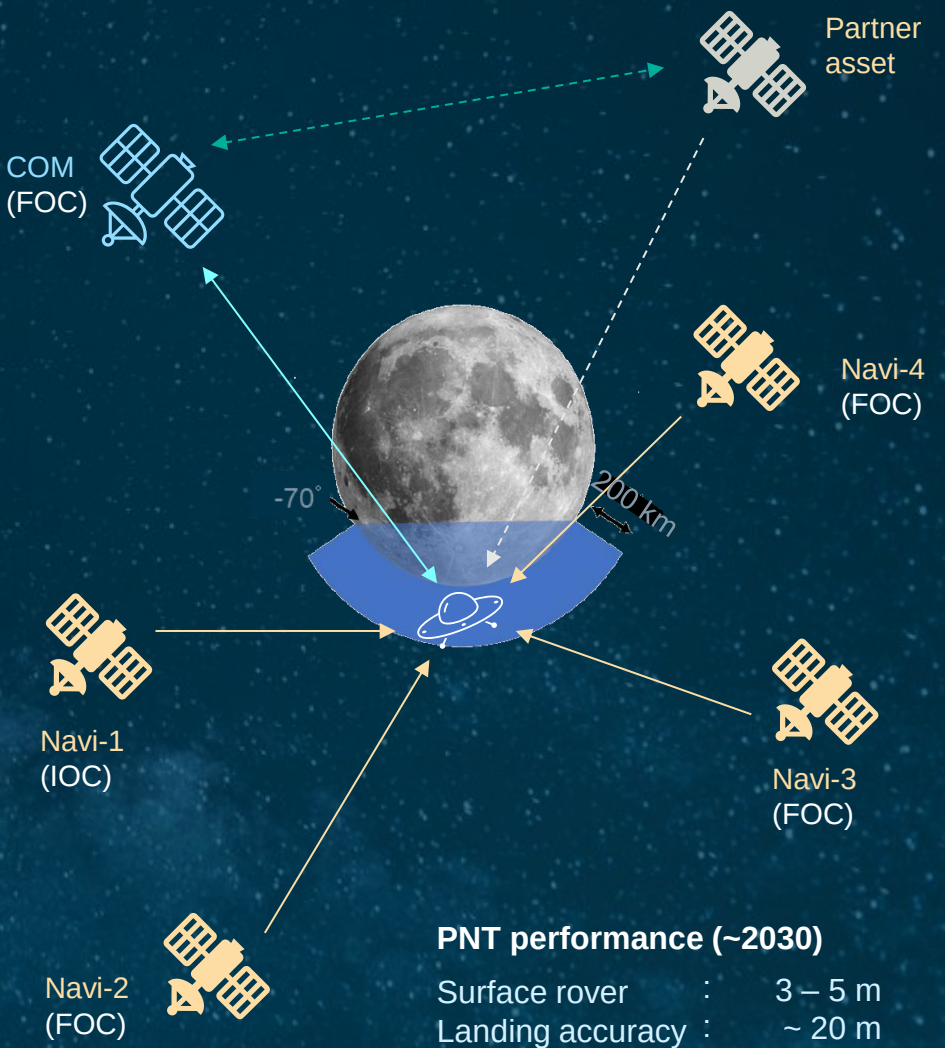
Interoperable LunaNET Standards

IOC in 2028
FOC in 2030
Evolutions 2030+

A Scalable System

Supporting all Mission Phases

Optimised For South Pole services [70-90º South]



PNT performance (~2030)

Surface rover	:	3 – 5 m
Landing accuracy	:	~ 20 m
Lunar orbiter	:	~ 30-60 m

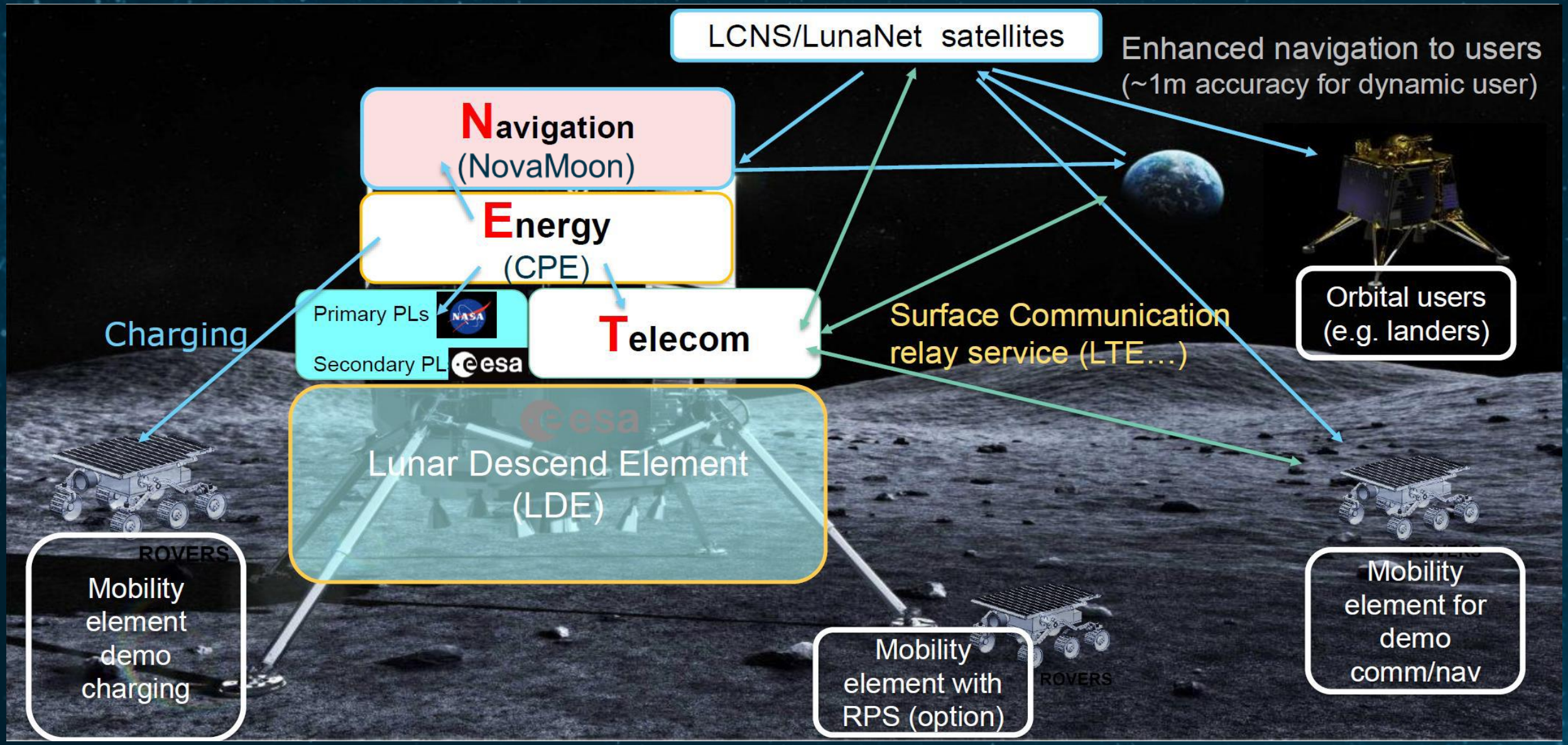
ESA ARGONAUT Programme is a family of planned lunar landers that will deliver infrastructures, scientific instruments, rovers, technology demonstrators and vital resources for astronauts on the lunar surface such as food, water and air.

ARGONAUT-1 lander (ArgoNET) will be launched in 2031 to land in the South pole region, providing continuous operations for 5 years, including periods of lunar night.

Recurrent Argonaut missions planned every 2-3 years

NovaMoon Payload: Further Enhancing Moonlight

NovaMoon: Candidate Payload to be integrated in ESA's Argonaut-1 Mission (ArgoNet – launch in 2031)

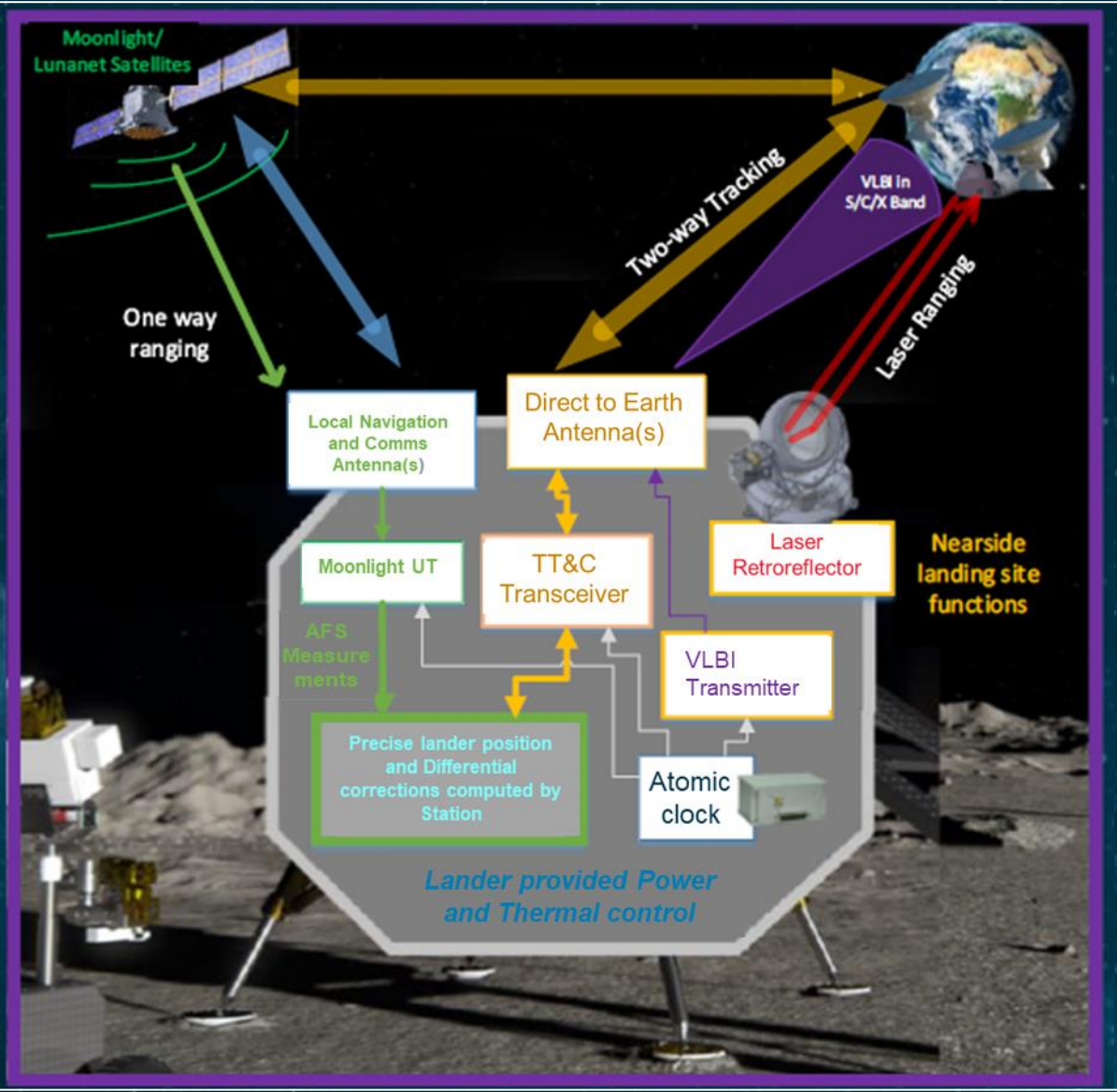


NovaMoon: Lunar Differential, Selenodetic and Timing station

1. Install **the first-ever reference local differential station on the lunar surface**
   Compute Moonlight NAV satellite pseudo-range corrections and broadcast these via the Moonlight PNT Channel → **decimeter level** navigation accuracies over the Lunar South Pole to standard LunaNet users.

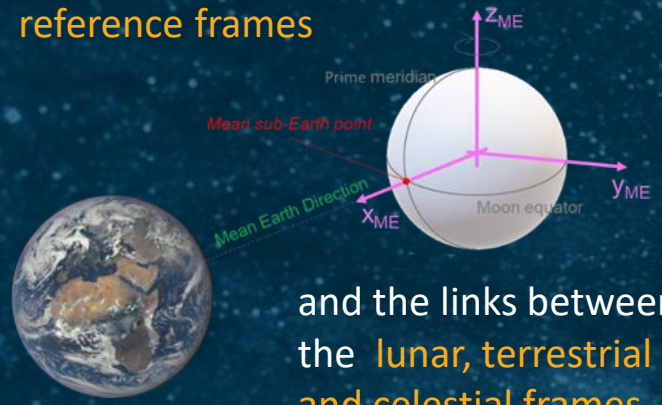
2. Install **the first-ever International "geodetic" Reference station on the lunar surface**
   Co-locating 4 geodetic techniques: Moonlight RX, VLBI TX, LLR and Two-way DTE ranging → locate the Argonaut lander station at **few cm-level** accuracy, setting the international standard for stations supporting the Lunar Reference Frame.

3. Install **the first-ever "Time Laboratory" station on the lunar surface**
   Supporting the realisation of lunar reference times and the standardisation of lunar time transfer protocols.



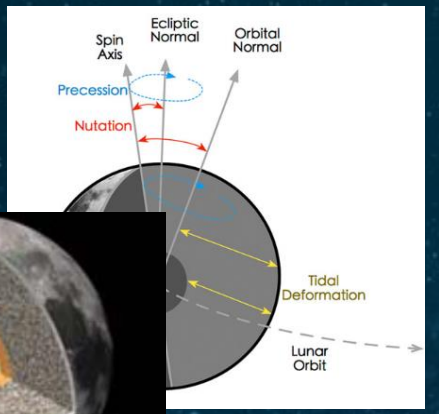
A wealth of potential scientific discoveries

Enhancing the accuracy of Lunar reference frames



and the links between the lunar, terrestrial and celestial frames

Allowing precise measurements of the Moon tidal deformations and Moon librations

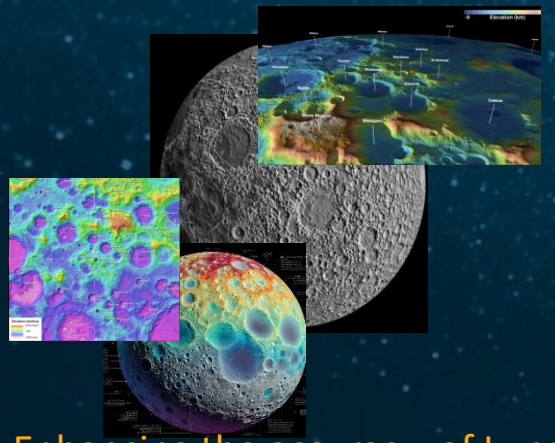


Improving the knowledge of the lunar gravity field, Moon rotation, solid core displacement, Moon interior, etc

Providing the first ever time laboratory on the Moon and setting the standards for time transfer protocols

Unique Fundamental Physics tests may be conceived thanks to the exceptional Earth-Moon relativistic long-baseline testbed.

With an active laser ranging time-tagging photons in space could help to research in quantum communication



Enhancing the accuracy of Lunar DEM maps allowing new lunar missions to happen

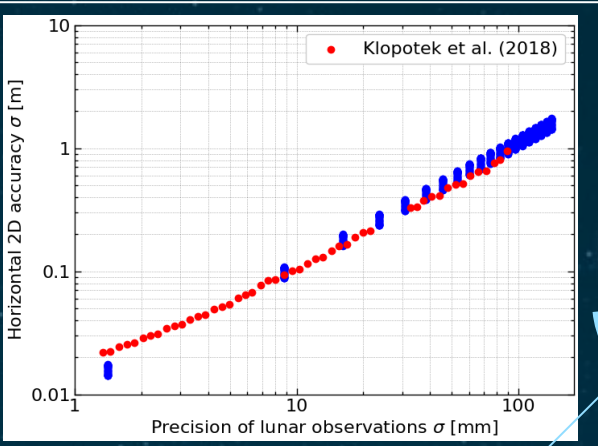
NovaMoon will catalyse the establishment of leading scientific groups and drive cutting-edge research across multiple disciplines

VLBI contribution

- **Best option for a 3D position estimation on the Moon**

  (LLR sensitivity is maximum along the line of sight, VLBI is highly sensitive to angular positioning which is perpendicular to the line of sight).

  All the scientific objectives require an accurate knowledge of the position of NovaMoon.



Royal Observatory Belgium & AntwerpSpace for ESA

- Inter-technique calibration

- Accurate measurement of **lunar librations**

- Determination of the tangential deformation **Love number** l_2

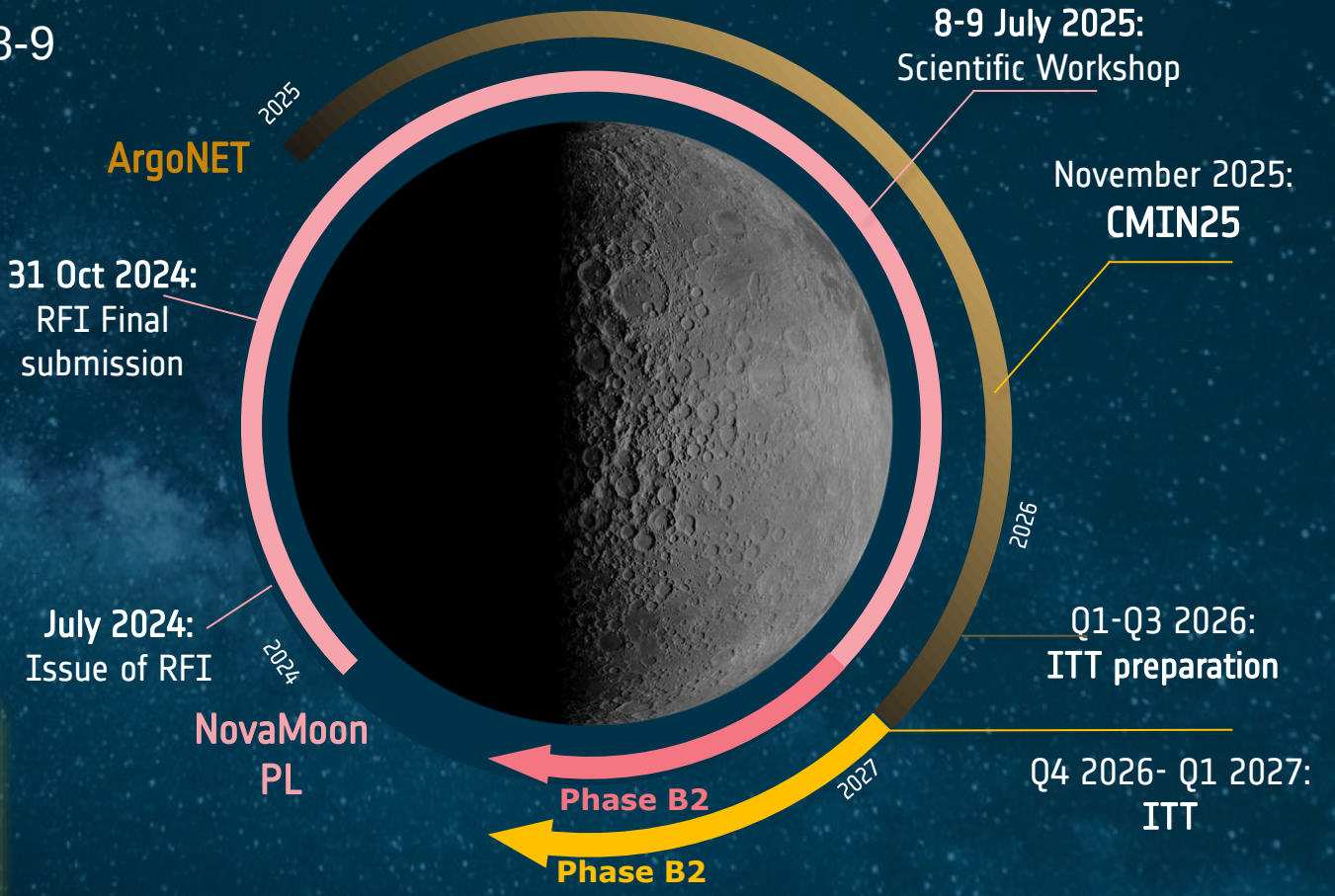
- Complement LLR observations for **general relativity tests**

Involvement of the scientific community

- **Definition and refinement of mission objectives and payload requirements**
  - Workshop on NovaMoon scientific objectives

    ESA/ESOC (and online) – July 8-9
- **Leverage on established experience**
  - Simulations
  - Previous experiments
  - …
- **Support towards CMIN2025**
  - White paper

Please get in contact!



Thank you for your attention!
Any Questions?

Points of contact:

Javier.Ventura-Traveset@esa.int

Richard.Swinden@esa.int

Sara.Bruni@ext.esa.int