Lunar Pathfinder - GNSS Receiver Experiment

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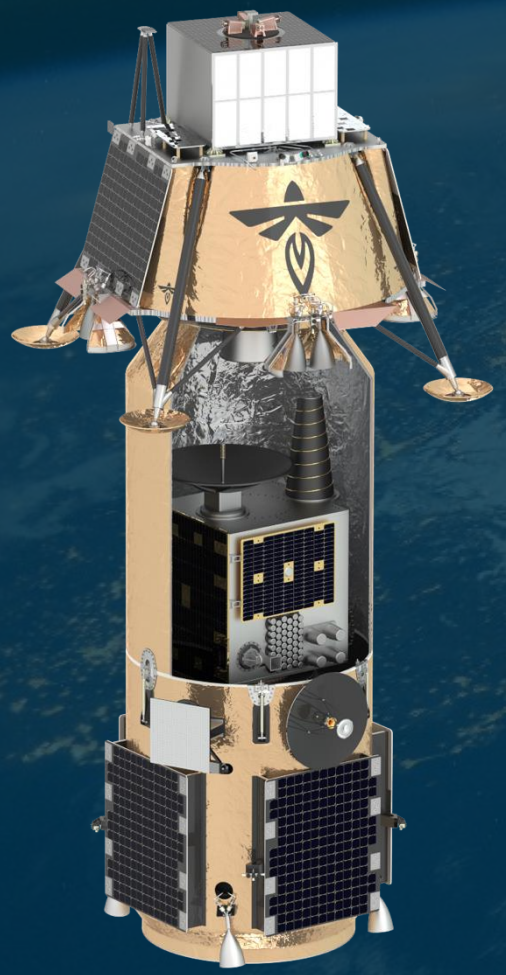
9th International Colloquium on Scientific and Fundamental Aspects of GNSS
Day 2 (26 September 2024) – Navigation for Lunar and for Space Applications: Systems and Technologies

Lunar Pathfinder

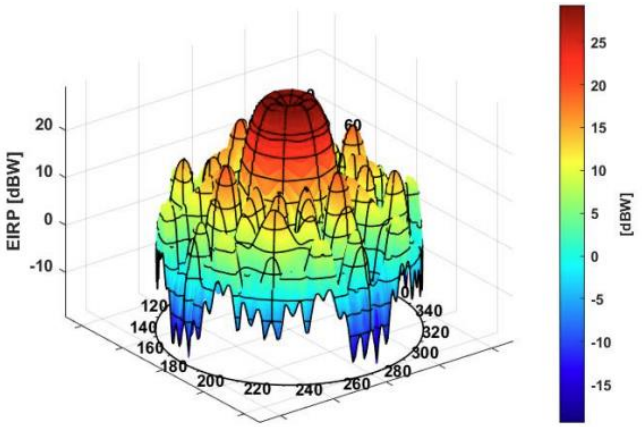


- **Commercial** Lunar Communication **Relay** Satellite (part of **Moonlight**)
- Public-Private Partnership (**PPP**) between **ESA** and Surrey Satellite Technology Limited (**SSTL**)
- Orbit delivery through **NASA**-led **CLPS** CS-3 program
- Will perform data realy operation for the **first** US lander on the **far side** (**LuSEE-Night**)
- Will host two hosted paylods: a **GNSS receiver** and **radiation monitor**
- **Launch:** Q4 2025
- **Exploitation:** Q1 2026 – Q3 2034

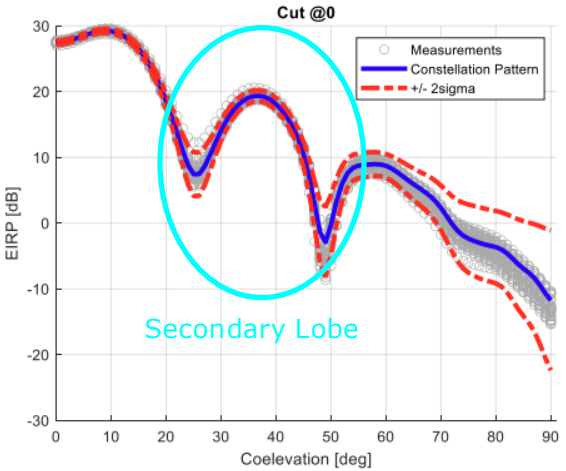
SSTL LUNAR

Challenges of GNSS beyond MEO

- **GNSS** satellites seen from the **other side** of the Earth
- Limited spilover of **main lobes**
- Largely seen through **secondary lobes**
- Low power due to large **free space path losses**
- Poor geometry (**high DOP**)



Courtesy: EUSPA
https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_Reference_Antenna_Pattern_v1.0.pdf



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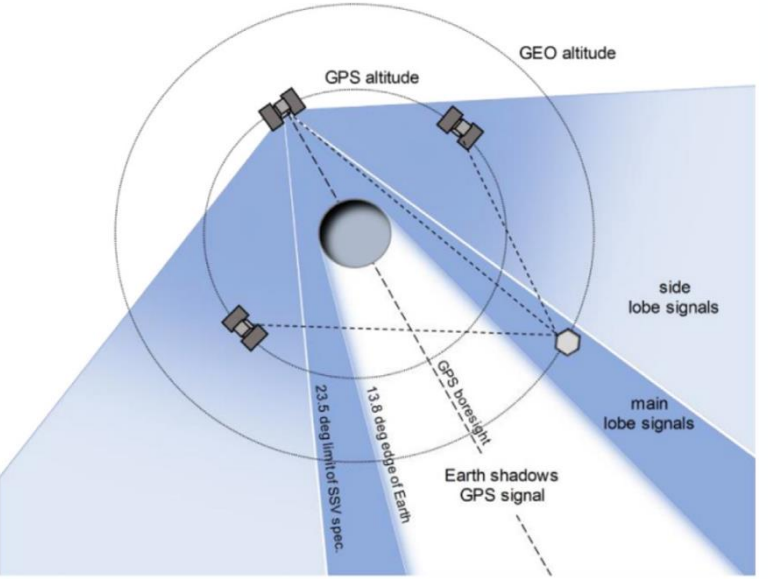
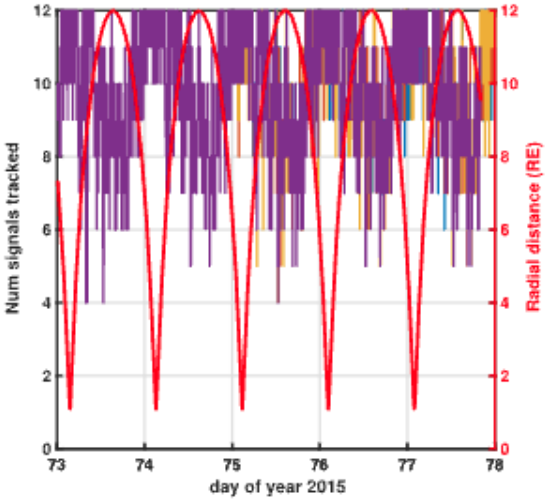


Courtesy: Donaldson, Jennifer E., et al. "Characterization of on-orbit GPS transmit antenna patterns for space users." *NAVIGATION: Journal of the Institute of Navigation* 67.2 (2020): 411-438.

Challenges of GNSS at Lunar Altitudes

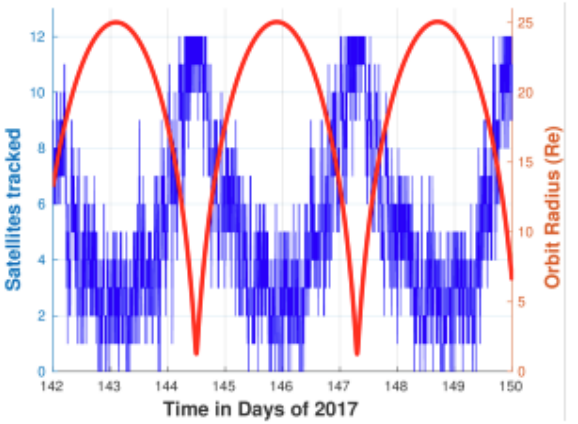
- **NASA MMS** (Magnetospheric Multiscale Mission)
- Current **record GNSS** based PNT at altitude
- Accuracy **improved** (factor 3-4) by using GPS **sidelobes**
- **Number** of GPS **satellites** at (~1/2 times the Earth-Moon distance) between **0** and **4**

MSS Phase #1



Courtesy: Winternitz, Luke B., et al. "Global positioning system navigation above 76,000 km for NASA's magnetospheric multiscale mission." *NAVIGATION: Journal of the Institute of Navigation* 64.2 (2017): 289-300.

MSS Phase #2



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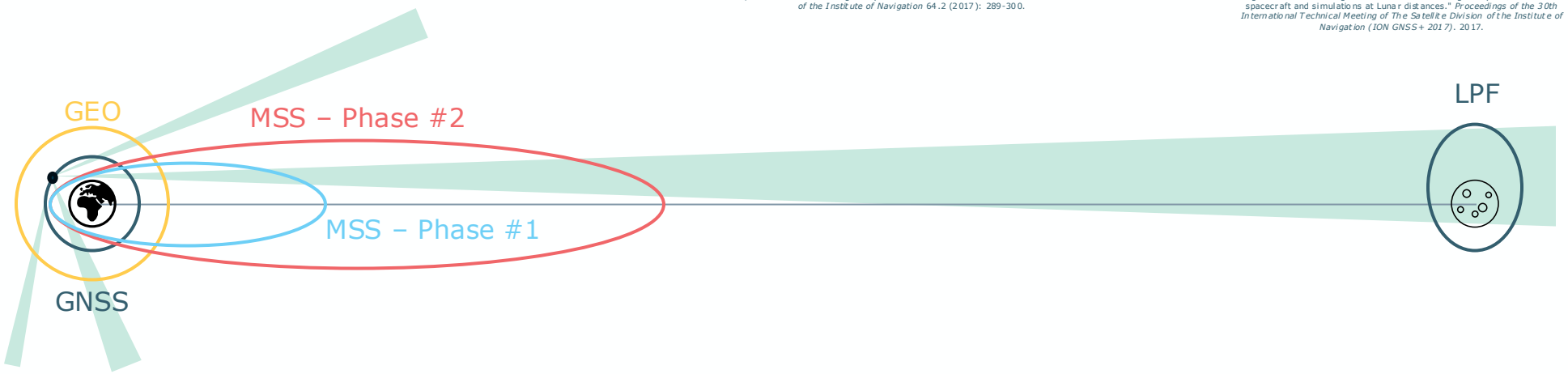
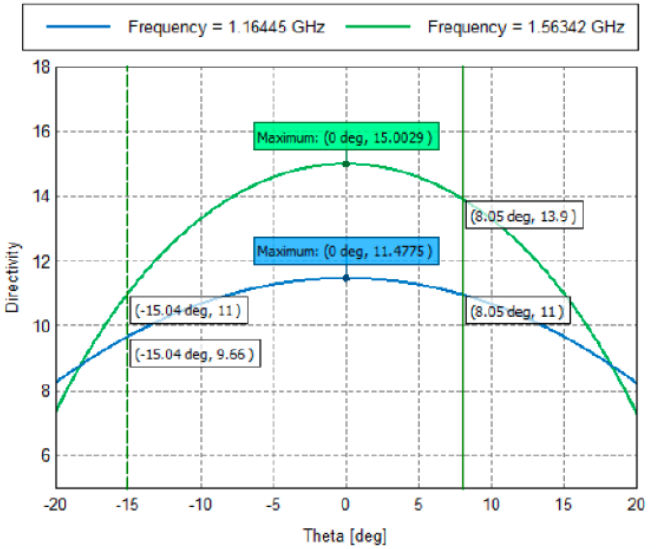


Enhancements of NaviMoon Receiver

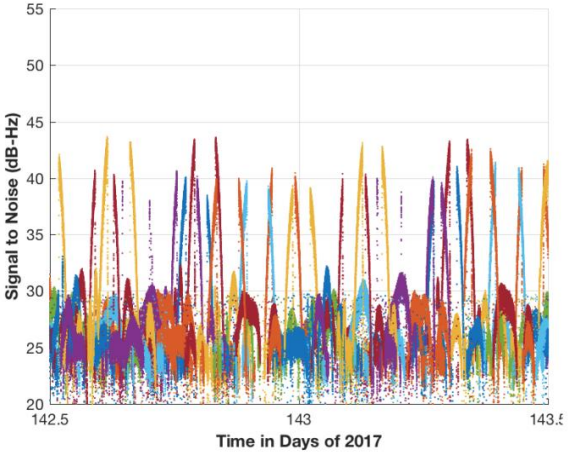
External LNA

Gain: 25 dB
NF: < 1.5 dB
Low N_0: -205.04 dBm/Hz

GNSS Medium-Gain Antenna



MSS Phase #2 – C/N0



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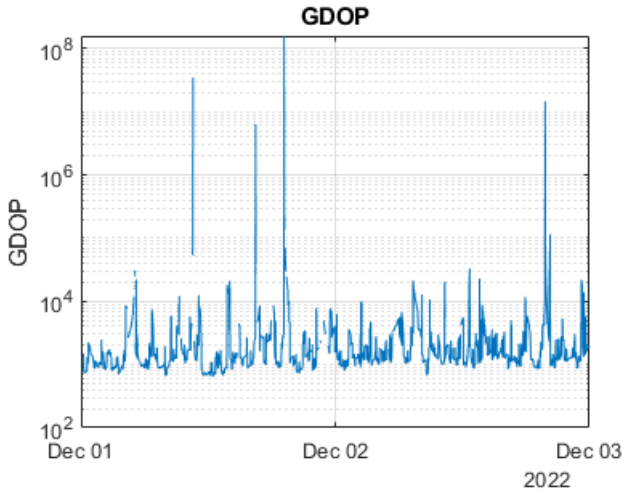
	Sensitivity	Receiver Antenna Gain	Constellations	Signals
MMS	~23 dB-Hz	6.5 dBi (hemispherical)	GPS Only	L1 only
Lunar Pathfinder	~15 dB-Hz (T) ~18 dB-Hz (A)	> 14 dBi (medium gain)	GPS + Galileo	L1/E1 + L5/E5

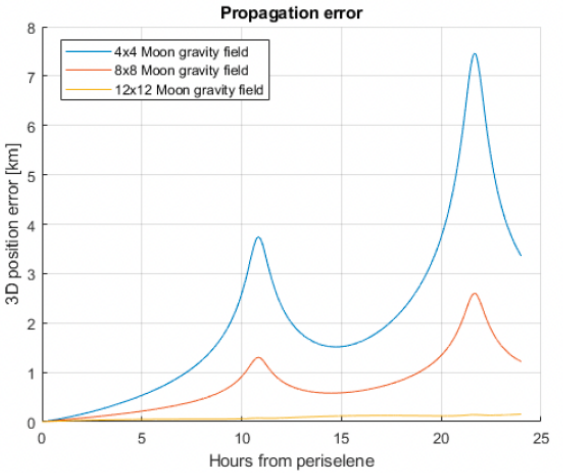
Challenges of High DOP

- **GDOP** at lunar altitudes can reach values up to 10,000 (beyond 100 already for **MSS Phase #1)**

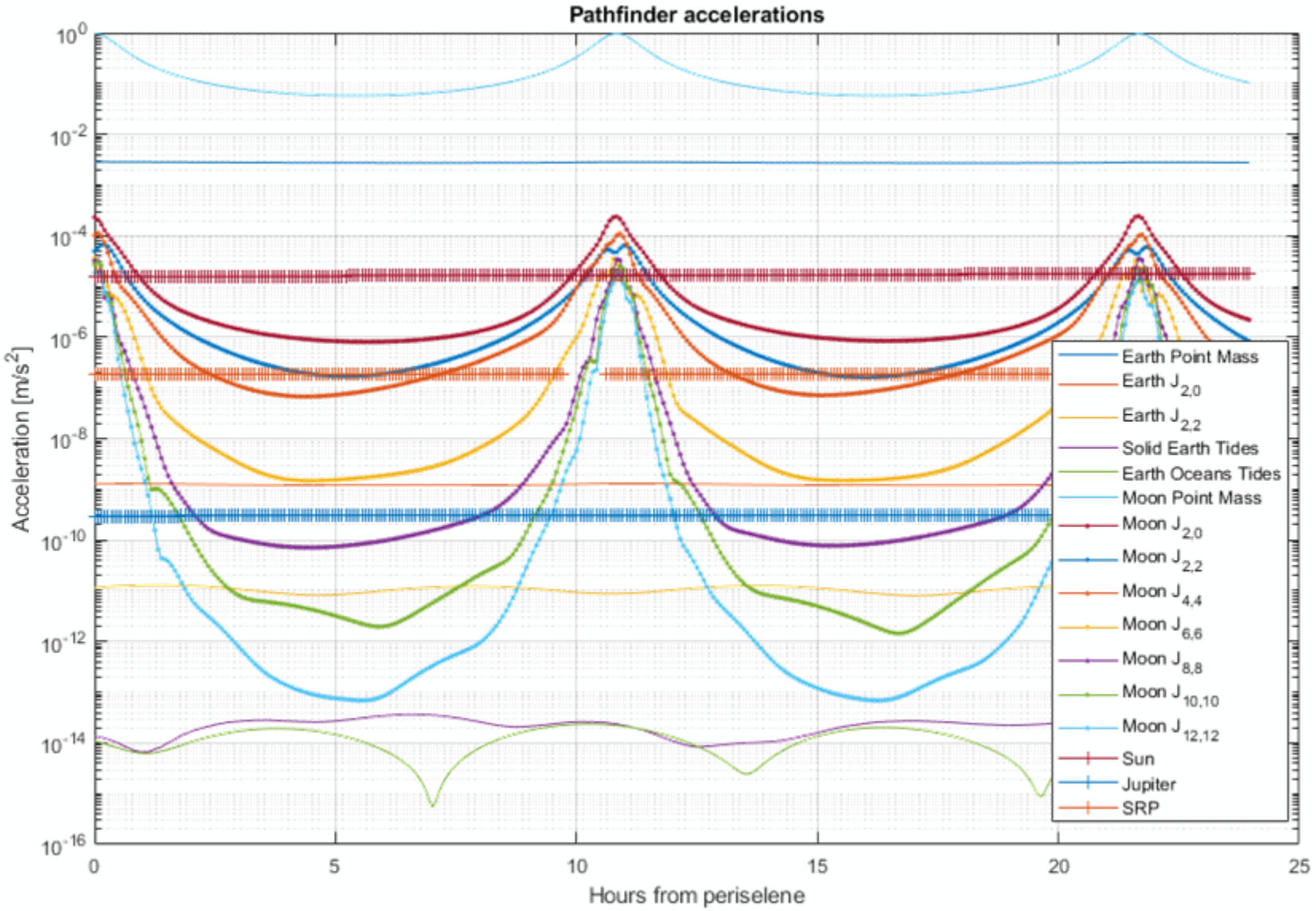
- Due to the stable dynamics of the orbiter, this issue can be overcome using a **reduced dynamic filter**

- Filter accelerations:
  - **Moon** gravity field (**12 x 12**) -> resulting in error ~100 m after 24 hrs
  - Point masses of the **Earth** and **Sun**
  - **Solar Radiation Pressure** (Cannonball model)



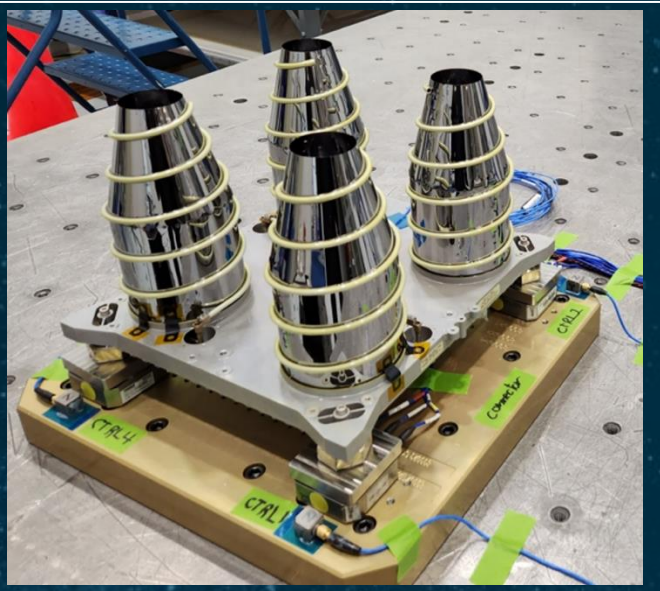


Lunar Pathfinder Accelerations

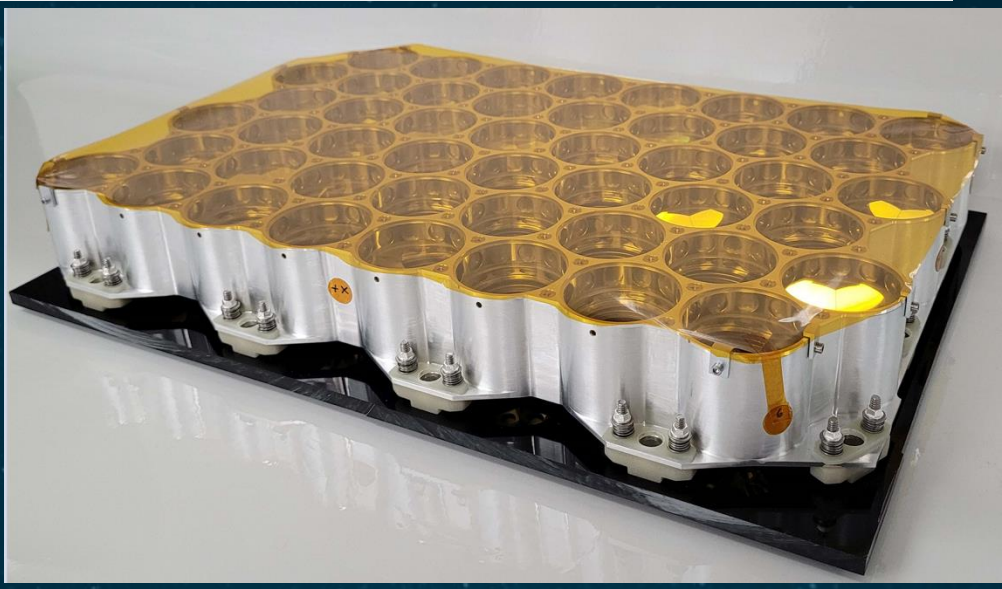


Lunar Pathfinder Experiment – Hardware Units

GNSS High-sensitive receiver
Flight unit (**SpacePNT**)



GNSS High-gain Antenna
Flight unit (**MDA**)

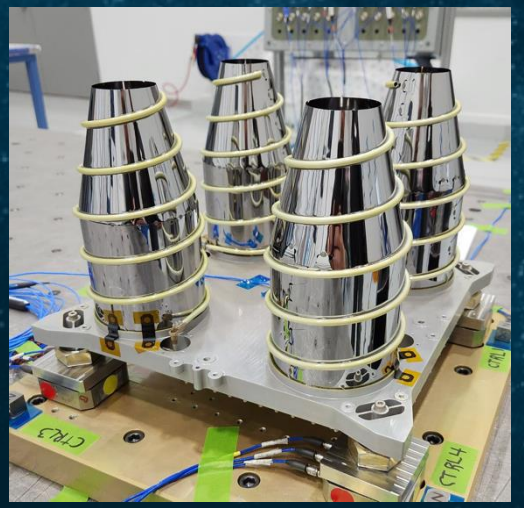


Laser Retroreflector
Flight unit (**NASA**)

All units are manufactured and tested

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

Lunar Pathfinder Experiment – Specifications



Parameter	Value
Acquisition sensitivity	<18dBHz
Tracking sensitivity	15dBHz
3D Position accuracy	< 100m RMS
3D Velocity accuracy	< 0.1 m/s RMS
Mass	1.5 kg
Size	23.4 x 12.1 x 6.4 cm
Power	< 12W
Constellations	GPS / Galileo L1/E1/L5/E5

SpacePNT NaviMoon Receiver Specifications

Parameter	Value
L1 boresight gain	> 14 dBi
L5 boresight gain	> 14 dBi
Polarization	RHCP
Mass	~1.8 Kg
Size	26x26x28cm

MDA Antenna Specifications

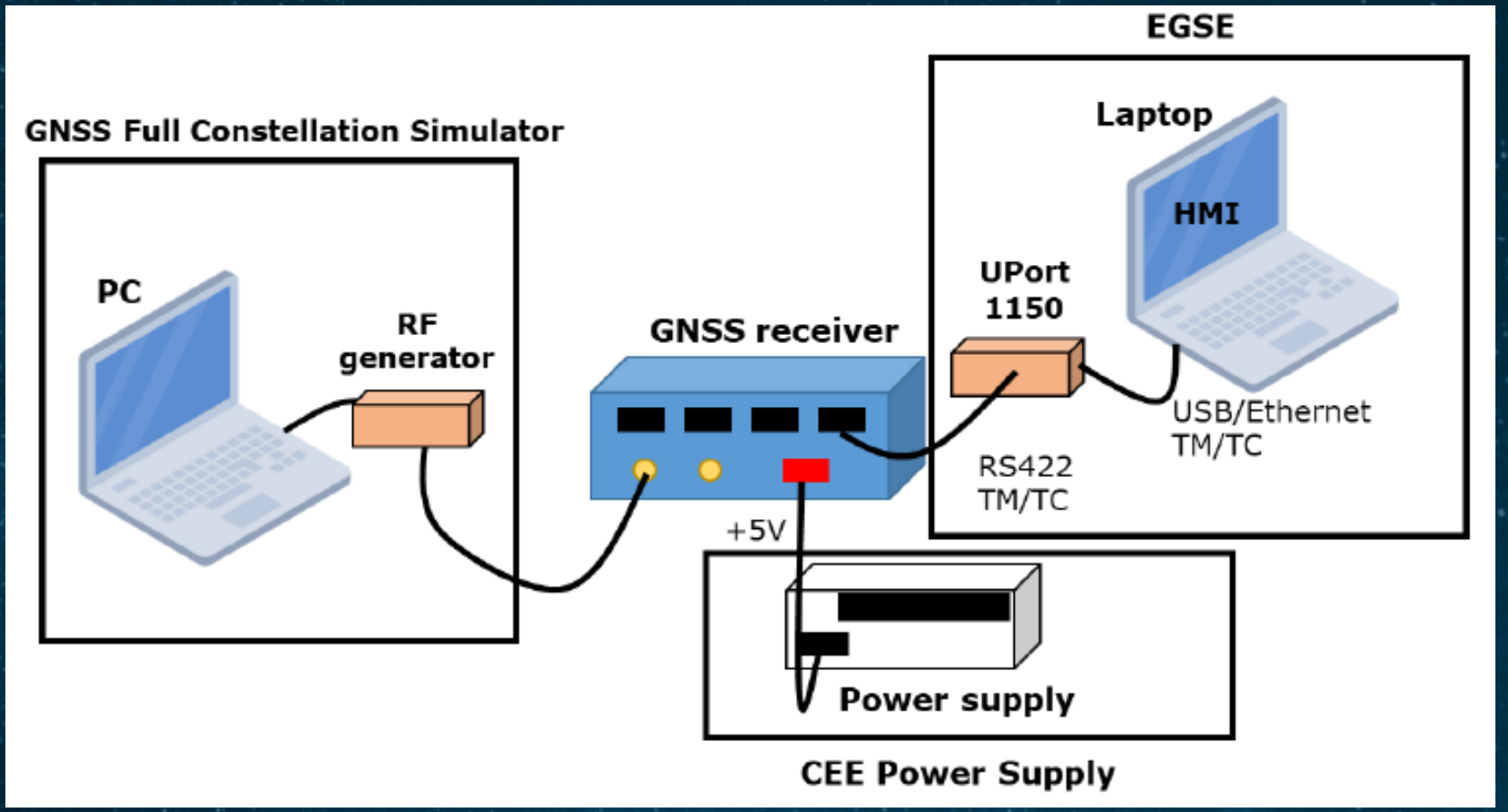
Hardware-in-the-loop Tests

The receiver has been tested with Skydel and **Spirent RFCS (single 9000)**

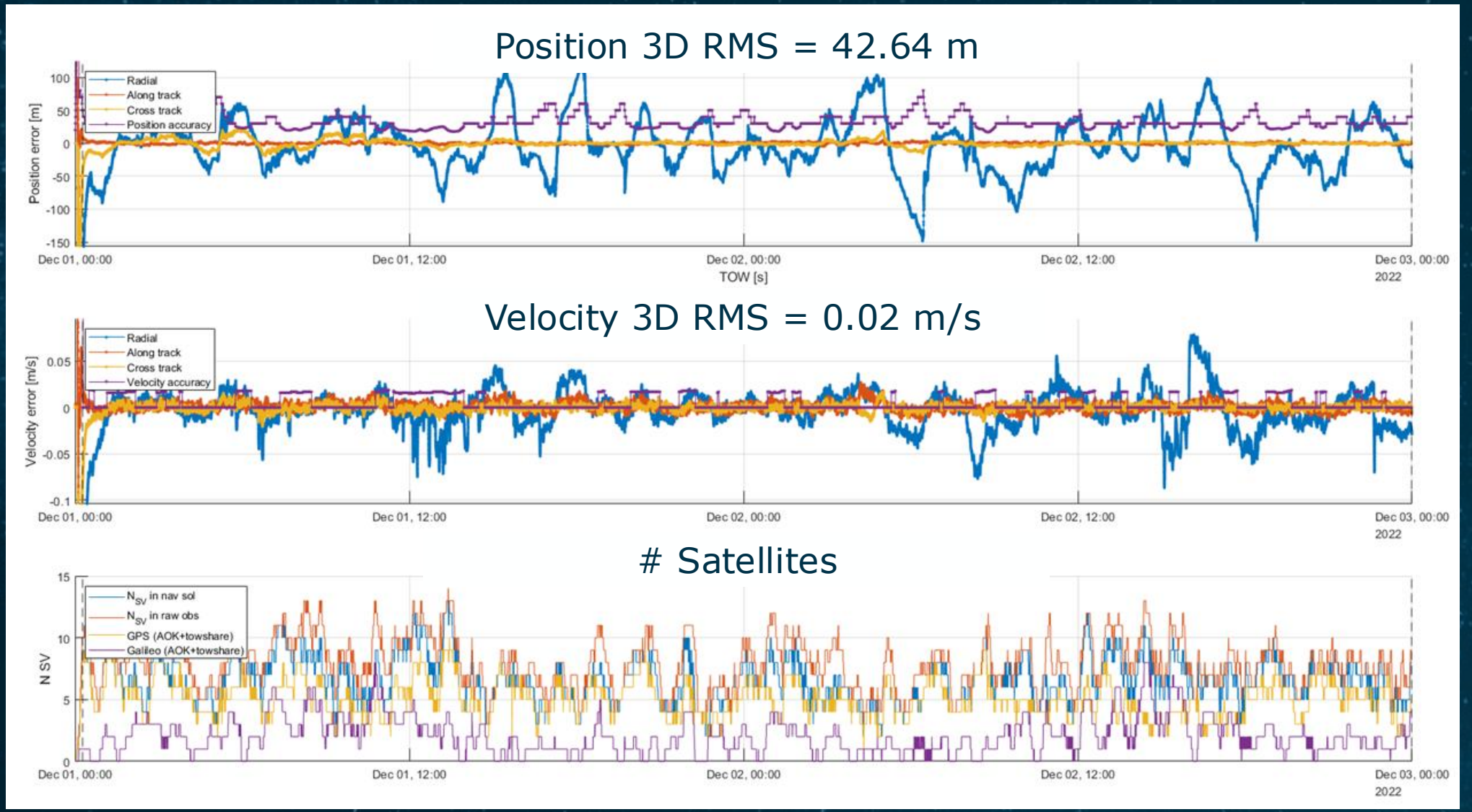
The reference user trajectory has been generated with **GMAT/GODOT**, using realistic dynamic models (tests performed in **MTO** and **NRHO** orbit)

Simulation power has been fine tuned to be representative of GPS and Galileo **EIRP** and Tx antenna **gain pattern**

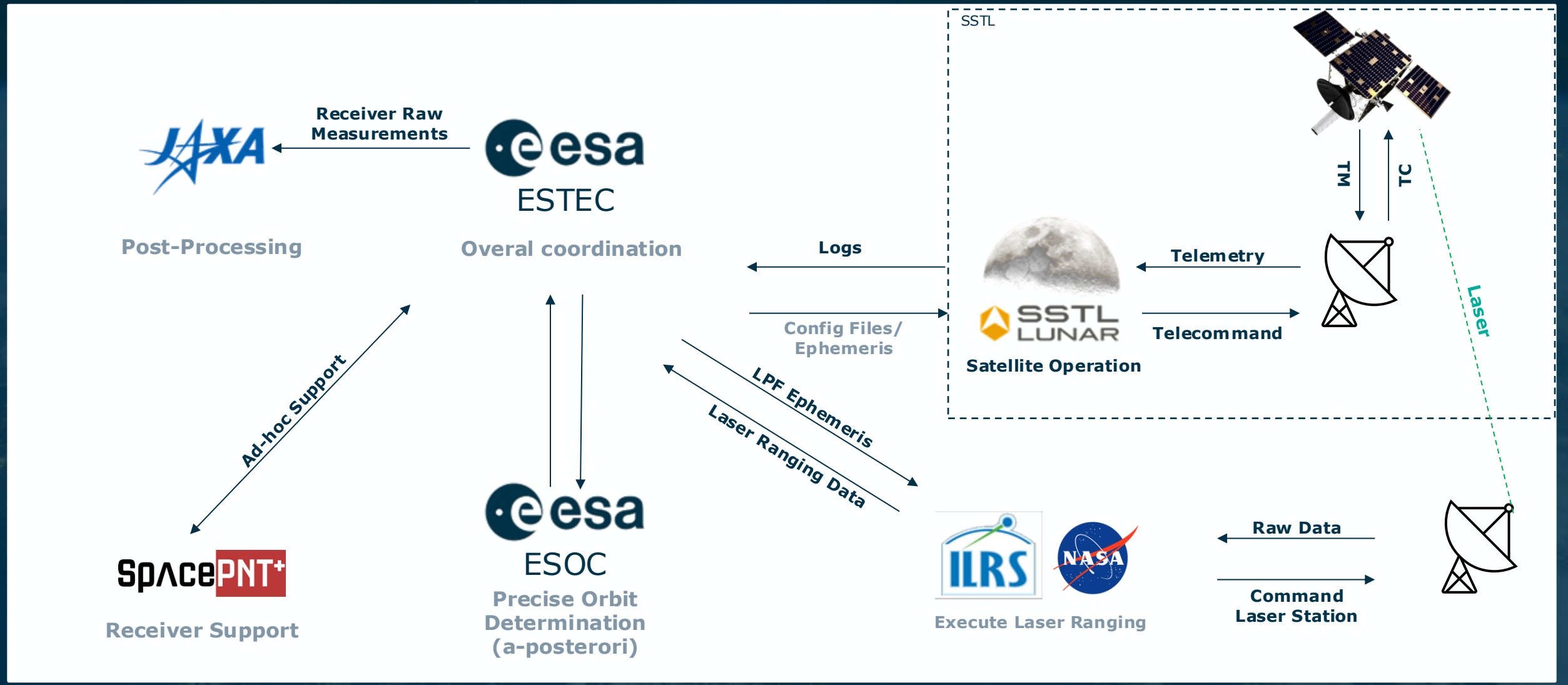
Receiver antenna gain pattern has been simulated accurately based on **real flight model**



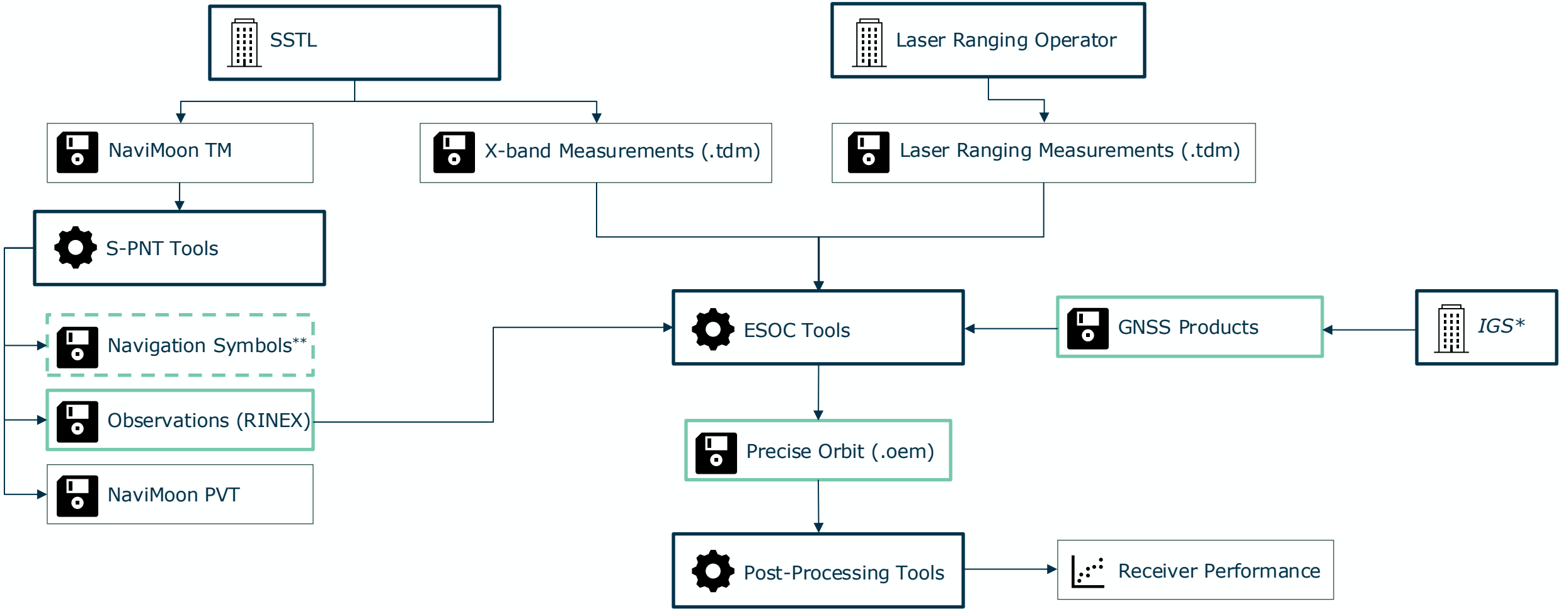
Lunar Pathfinder – Hardware-in-the-loop Test



Experiment - Actors

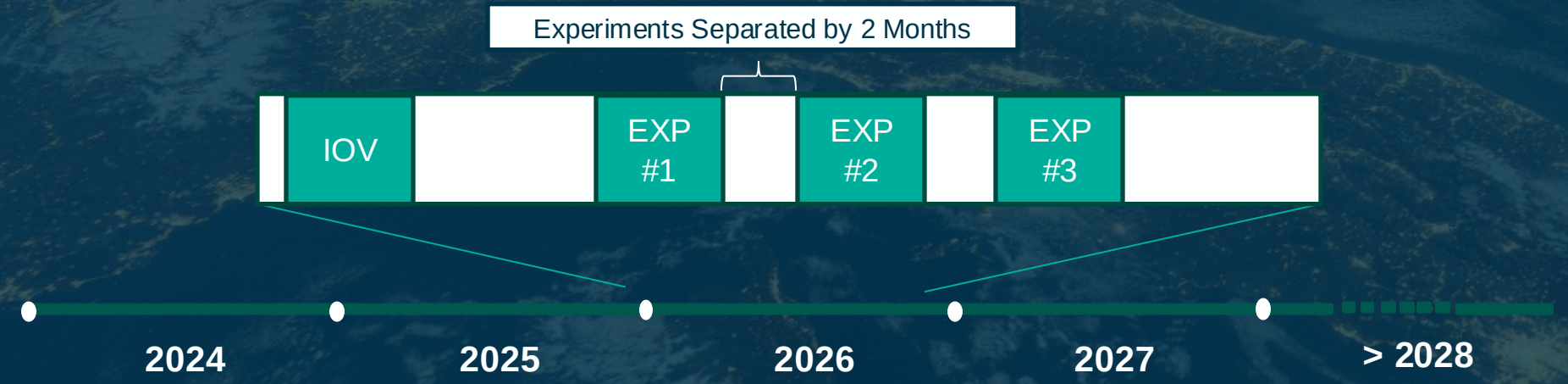


Experiment Data Processing



- The data in the green boxes will be made available (on request)
- **Parser may be needed to convert this

Experiment – Schedule (notional)



Questions

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