Enabling Future Lunar Operations through PNT: A GMV User Perspective

Workshop on Cislunar Positioning, Navigation, and Timing (PNT)

Danilo Forte

INNOVATING SOLUTIONS

Contents

GMV Today:
A Global Technology Group

Multinational technology group

Headquarters in Spain (Madrid)

100% private capital

Founded in **1984**

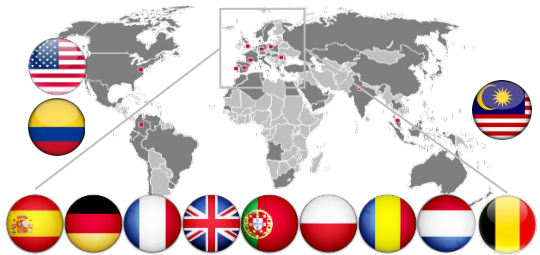
3,000+ staff

Roots tied to Space

Quality excellence

CMMI DEV /5 SM
Exp. 2016-09-16 / Appraisal #20109

Subsidiaries in 12 countries



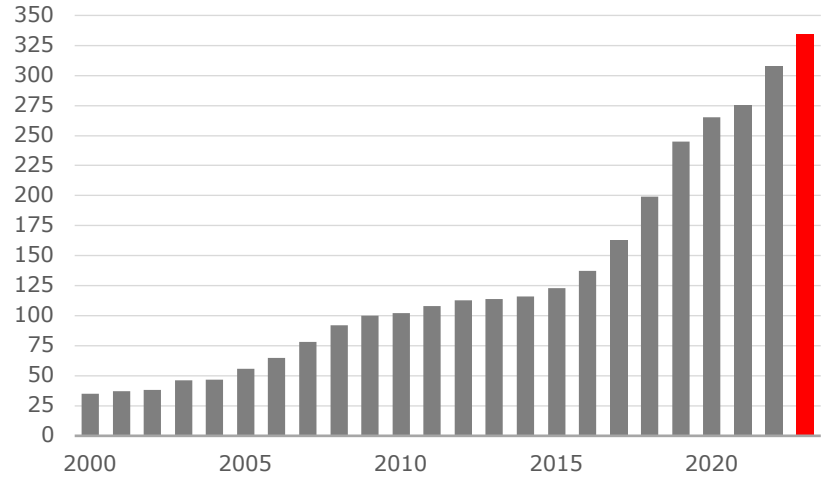
6th European space industry in headcount

1. Airbus
2. Thales
3. ArianeGroup
4. Leonardo
5. OHB
6. **GMV**

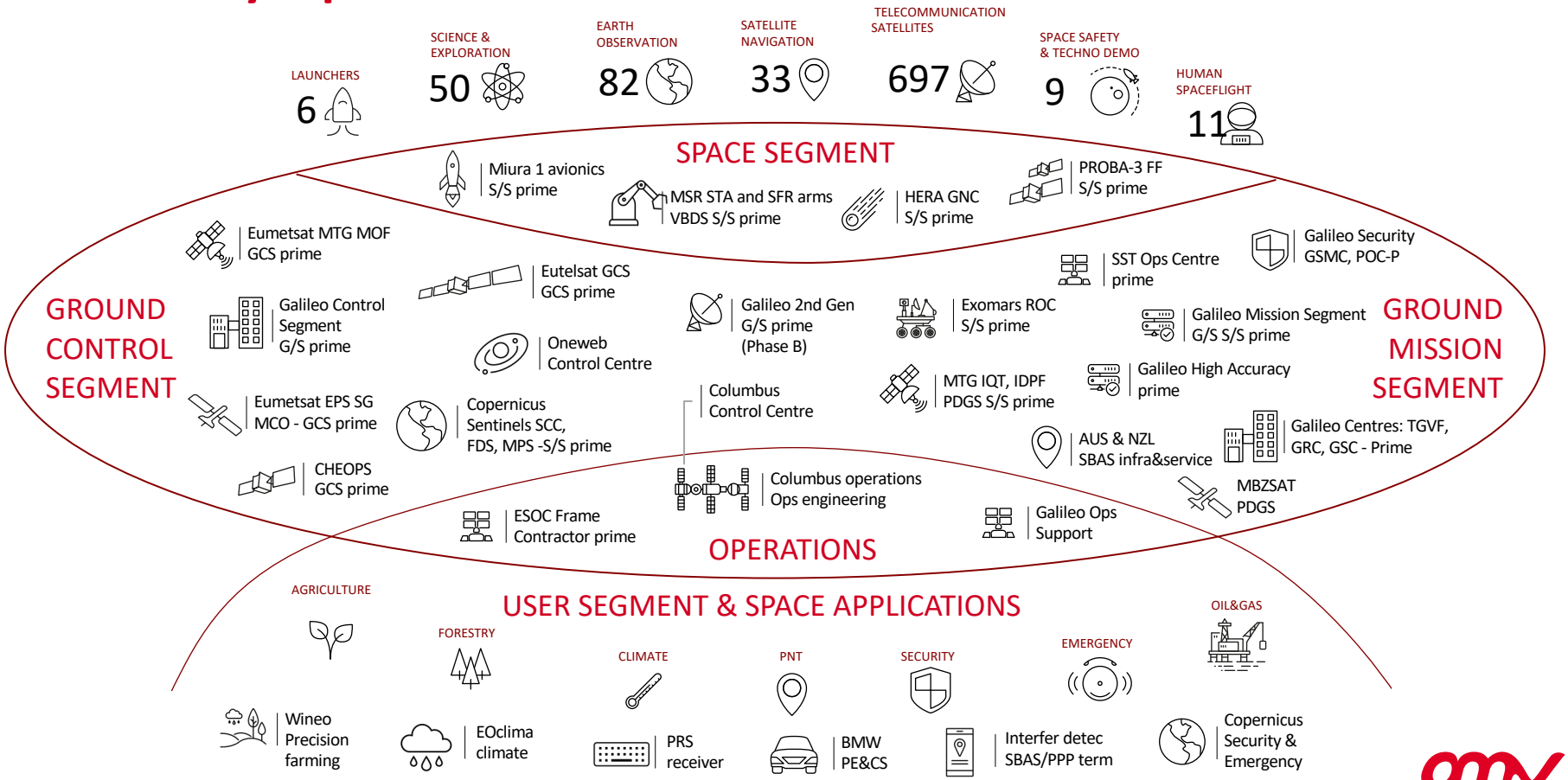
Aeronautics, Space, Defense, Security, Transportation, Healthcare, Banking & finances, and ICT industries

Space	Defense	IT	Transport
56%	11%	16%	17%

Sustained growth: 330 M€ worldwide revenue



GMV Today: Space



Why Lunar PNT matters to users

Potential for operational gains

From a user point of view, the real question is what Lunar PNT can enable operationally: how fast can the assets move, how autonomously can they operate and how much science can be performed during an active exploration window.

1

Faster operations

- Real-time orbital assets' ODTS
- Continuous motion vs top-and-go driving
- Faster and longer traverse

2

More autonomous operations

- Reduced dependency on ground-based ODTS and planning
- Onboard decision-making

3

Higher returns for day of operations

- Less time spent in engineering operations
- Better and more repeatable data
- Improved science-to-operations ratio

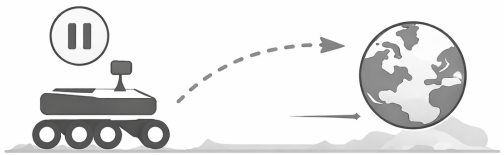
Lunar PNT as an operational enabler

PNT as a multiplier of autonomy, efficiency, and robustness

Lunar PNT fundamentally changes the operational paradigm, enabling higher autonomy, reduced need for ground intervention, and opening the possible for more scalable operations, involving multiple Lunar assets.

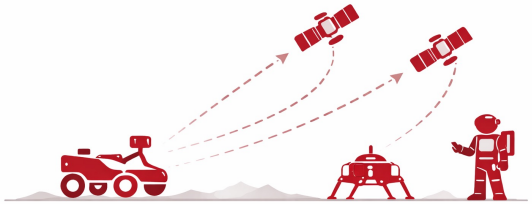
Without Lunar PNT

- Absolute navigation requires Ground in the loop
- Pre-planned mission
- Stop-and-go rover operations and slow speed



With Lunar PNT

- Real-time Absolute PVT with no ground in the loop
- Increase on-board autonomy
- Continuous rover operations up to 1 m/s



From Earth GNSS to Lunar PNT operations

A fundamentally different operational environment

Unlike Earth GNSS, Lunar PNT services are more limited. There are only a limited number of signals at reduced performances while the user experiences challenging environments with extended mission durations.

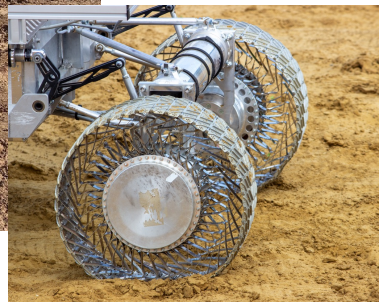
- GNSS is the natural starting point for Lunar PNT user expectations
- Lunar PNT will initially offer fewer assets and lower performance
- This requires a different operational paradigm, leaning more on autonomy
- Sensor fusion is a key enabler for user-level PNT performance

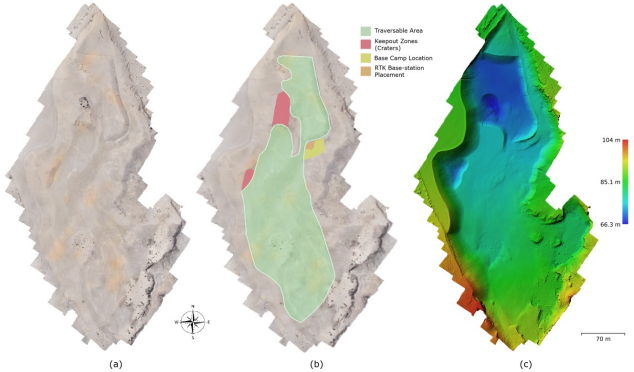
LUPIN mission context

Enabling High Performance PNT in Lunar Environment

LUPIN, funded by ESA in the frame of the NAVISP program:

- Aims to demonstrate a high-performance PNT engine for rover surface operations
- Performance is achieved by fusing Lunar PNT services with traditional rover sensors (visual, inertial, terrain-based, celestial)
- The RAPID platform is used to integrate and validate the PNT engine in realistic conditions
- Representative datasets were collected during analogue field trials in Fuerteventura





Fast & autonomous rover navigation

From stop-and-go driving to continuous autonomous motion

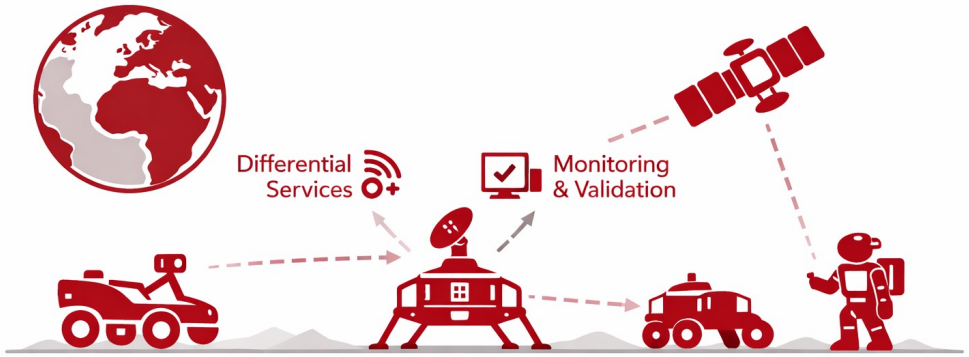
- **High-speed rover operations up to > 1 m/s**
  An order-of-magnitude increase w.r.t. traditional planetary rovers
- **Autonomous path planning and hazard avoidance**
  For continuous driving with minimal ground intervention
- **High-performance PNT engine as a key enabler**
  For robust pose estimation under demanding dynamics
- **Enabled by Lunar PNT services and advanced GNC**:
  Sensor fusion and autonomy

Lunar PNT with a surface reference and service station

NovaMoon from a user point of view

Lunar PNT services, enhanced by a Lunar surface station, such as the potential **NovaMoon** payload, for which **GMV** is prime as part of the **ESA's funded ArgoNET Phase A/B1 work**, can enable even more user operation

- NovaMoon would introduce a surface-anchored PNT service layer, complementing the segment of the Lunar PNT services
- This would anchor position and time to a stable lunar surface reference
- It would enable additional services as local augmentation provision, monitoring, and validation of Lunar PNT services
- And act as a surveyed reference point within the Lunar PNT framework for long-term operations and interoperability

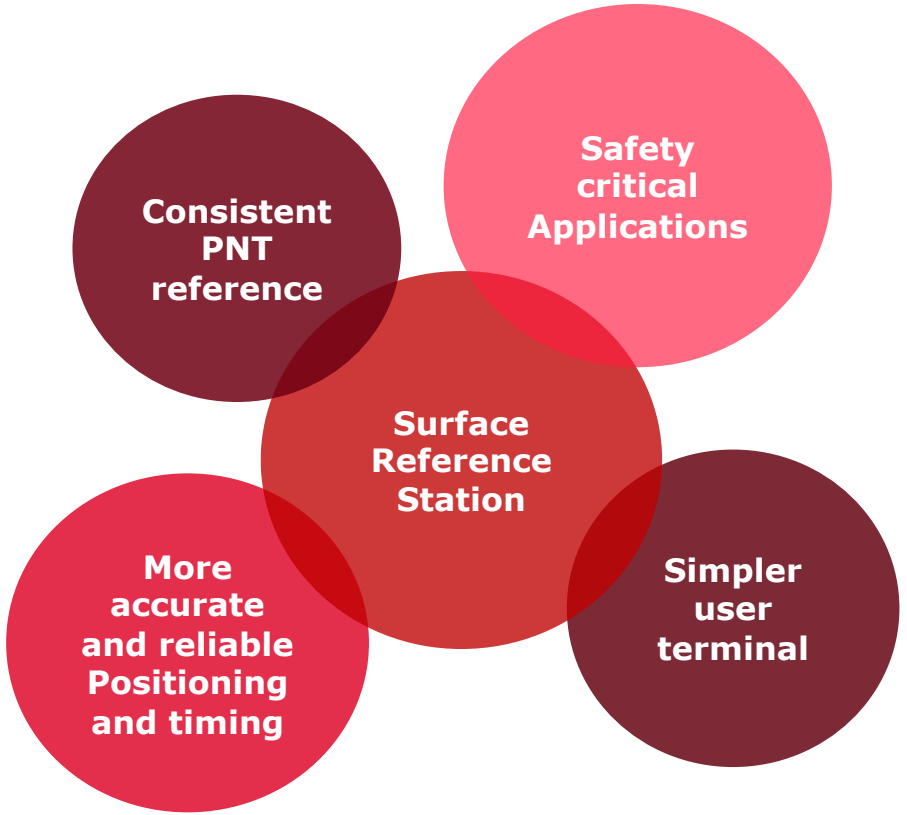


User capabilities enabled by NovaMoon

Improving performance and for users

NovaMoon enables user-level capabilities such as faster positioning convergence, improved robustness, and consistent reference frames, all of which directly benefit surface operations.

- **Faster and more reliable positioning convergence for surface users**
- **Consistent position and time reference across missions and assets**, enabling repeatable science, shared maps and coordinated operations
- **Improved robustness enabling safety-critical applications** such as crew Landing and EVA navigation
- **Reduced reliance on complex onboard sensor fusion** for simpler, for more cost-effective user PNT solutions

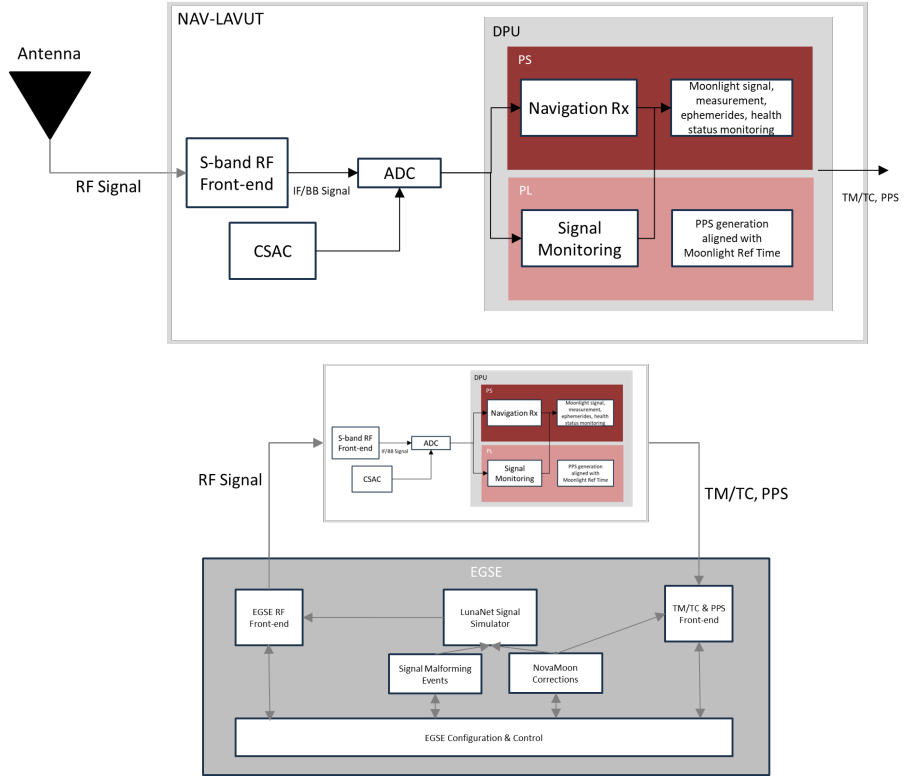


NAV-LAVUT – A LunaNet AFS receivers

Navigation Lunar Augmented Validation User Terminal

ESA GSTP Element 1 activity awarded:

- **Interoperable lunar PNT Receiver EM**: LunaNet-compatible PNT engineering model with one-way ranging, signal monitoring, and integrity functions.
- **Multi-LNSP Compatibility + NovaMoon**: decoding of multiple LNSP signals per LNIS and support NovaMoon correction integration.
- **Adaptable Navigation Algorithms**: Create algorithms adaptable to orbital and surface missions, emphasizing real-time reduced-dynamic orbit solutions and extensibility for landers.
- **Moonlight System Validation**: Enable enhanced validation of Moonlight PNT services via integrated monitoring and integrity checking.
- **Flight Model Roadmap**: Define the path from engineering model to qualified, SWaP optimised flight models, by 2029.

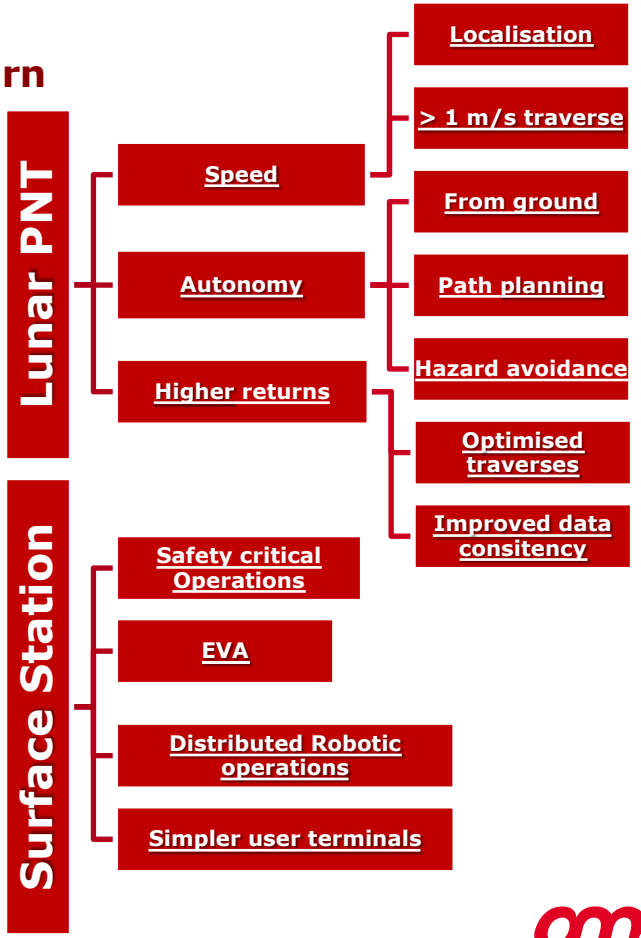


Science and productivity gains

More coverage, longer traverses, higher scientific return

As shown, the change in Concept of operations enabled by Lunar PNT can directly improve science and mission return:

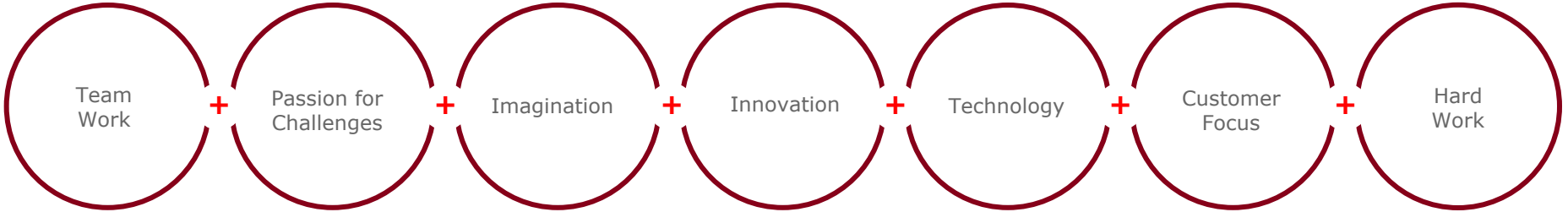
- Enabling for the user a more autonomous and faster surface operations
- Improved reliability and navigation confidence increase science return, allowing larger coverage, optimised traverses and fewer engineering activities
- Differential Lunar PNT could enable coordinated robotic operations, for large structure assembly and In-situ resource utilisation
- With a surface station, also safety-critical and cost-effective operations become more plausible



Key takeaways

Lunar PNT as a foundation for future surface operations

- **Lunar PNT is a key enabler of future lunar surface operations**: Speed, Autonomy, Performance and scalability
- **LUPIN demonstrates the immediate operational benefits of Lunar PNT**: faster, more autonomous rover navigation and potential for Increase science return
- **NovaMoon could enable even more operational concept through a surface reference station:** With higher performance trusted PNT
- **Together, Lunar PNT and NovaMoon would enable autonomous, more efficient and safe Operations:** From robotic exploration to future human operations and scientific and commercial exploitation



Thank you

Danilo Forte
Danilo.forte@gmv.com

gmv INNOVATING SOLUTIONS