

Lunar Laser Ranging (LLR) & Time Transfer

Science with LLR

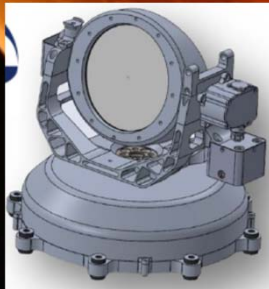
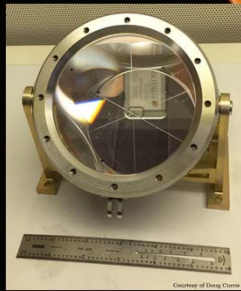
- *Fundamental Physics Tests*
- *Selenophysics / Selenodesy*
- *Planetary ephemeris*

And maybe in a near future :

Gravitational waves detection with LLR&SLR

Beyond the General relativity

- constrain of new theories of relativistic gravity
- open window for dark energy/matter understanding



LLR Network

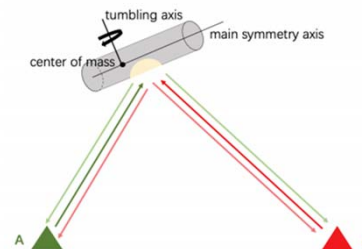
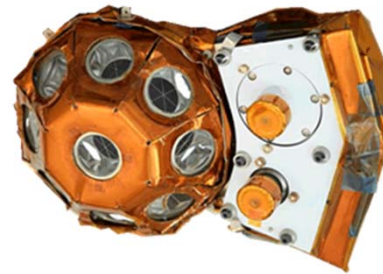
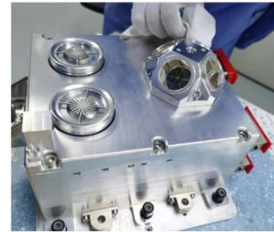
Apollo (USA), Grasse (France), Matera (Italy), Wettzell (Germany), + Chinese/Russian/South Africa stations in progress

LLR Analysis centers

- Goddard Lunar Data Analysis Center (GLD AC), Greenbelt, MD, USA
- the Paris Observatory Lunar Analysis Center (POLAC), Paris, France;
- the Institute of Geodesy (IfE), University of Hannover, Germany;
- the National Institute for Nuclear Physics (INFN), Frascati, Italy;
- The Jet Propulsion Laboratory (JPL), Pasadena, USA
- the Institute of Applied Astronomy Russian Academy of Sciences (IAARAS), Saint Petersburg (Russia).

5 reflectors on the Moon and new reflectors in a near future (2024-2025) on the Moon & on orbiter :

- NASA-NGLR-1&2
- ESA-MoonLIGHT & Lunar Pathfinder
- CNSA-Tiandu-1 & CAS-1



Science and application with Transponder

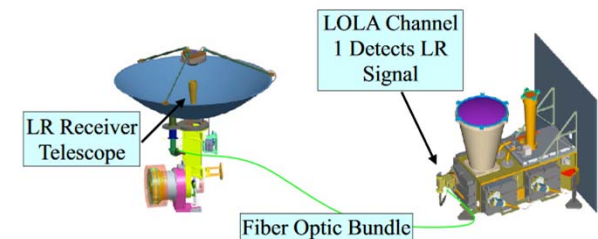
- *Time & frequency transfer and clock synchronization between ground & space*
 - *Interplanetary laser ranging*
 - *Fundamental physics*
 - *Chronometric geodesy*
- *Atmospheric propagation delay*
 - *Laser communication*
 - *Navigation*

On-going :

- CSS-LTT (2022, underway) 2way asynchronous

Up-coming :

- ACES-ELT : launch in early 2025
- LTT on CAS-1





LLR & TT standing committee News

- ***LLR space segment*** => new LRR soon (NGLR should be launched in Q4 2024)
- ***LLR stations***
 - Matera => upgrade of the station => see the presentation of Vincenza Luceri Session 3
 - Wettzell => upgrade of the laser amplification stage => see the presentation of Johann Eckl Session 4
 - Apache Point => data release in february 2024 : a reprocessing of all pre-NASA data
 - Sun Yat-SEN UniversCity => LLR on all the 5 LRR in 2019 ; 2023 LLR of A15 @full Moon conditions
- ***LLR analysis centers***
 - IAA RAS => Ephemeris of the Moon EPM2023 => see presentation of Eleonora Yagudina Session 4 part 2
 - IfE => ERPs + DLLR simulations + testing the general relativity => see presentation of Zhang Mingyue Session 4 part 2
 - POLAC => looking for gravitational waves => see presentation of Diego Blas Session 6
- **+ Institutional discussions on Lunar Reference & Time Frame**



LLR & TT standing committee

General remark for LLR

Lunar Laser Ranging is reliving a golden age thanks to all the effort done :

- by the space agencies, to send new laser retro reflector and orbiter equipped with
- by the space agencies and the institution world wide to support the optical ground stations

The ILRS community is facing new scientific challenges but also a strong support for all the PNT activities around & on the Moon.

The ILRS database for LLR measurement is weak w.r.t SLR measurement

=> Each quality LLR data is very precious !

Valorization of the SLR/LLR observations is a part of our job.

But thanks to the ILRS community and its database, it is not one but many valorization during the years.

So for that, I encourage all the new LLR observations to be shared as soon as possible through the ILRS database.



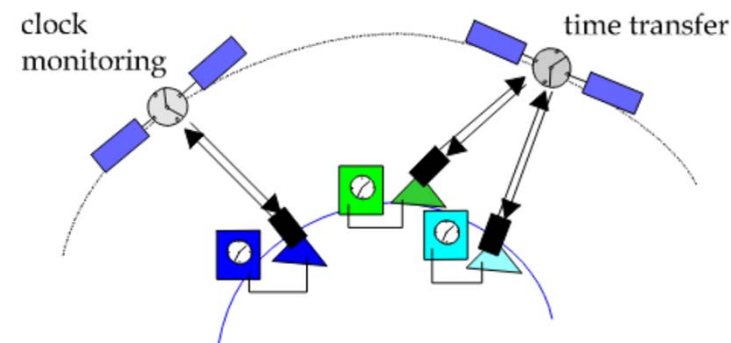
LLR & TT standing committee

News

- **TT**
 - See presentations of session 7 for the chinese activities + presentation of Abdelrahim Ruby session 6
 - ESA-ACES => see the presentation of Jan Kodet Session 1

Time Transfer in common view + Time Transfer in non common view thanks to active LLR
On ground => Good clock, good time scale + SLR capabilities & dedicated calibration

What are the needs regarding the ILRS network ?



LLR & TT standing committee



The poster features a central image of a satellite in orbit above the Earth, with the Moon's surface visible in the foreground. The Earth is surrounded by a network of GNSS satellite orbits. In the top left corner, there is a circular logo with the ESA logo and the word 'moonlight' around a stylized Earth and Moon. In the top right corner, the ESA logo and 'SpacePNT+' are displayed. The title 'Lunar Pathfinder - GNSS Receiver Experiment' is prominently displayed in the center-right. Below the title, the names of the participants are listed: Floor Thomas Melman, Michele Scotti (SpacePNT SA), Richard Swinden, Javier Ventura-Traveset, and Brice Dellandrea. The text '9th International Colloquium on Scientific and Fundamental Aspects of GNSS' and 'Day 2 (26 September 2024) - Navigation for Lunar and for Space Applications: Systems and Technologies' is also present. At the bottom, there is a row of flags representing various countries and the ESA logo with the text 'THE EUROPEAN SPACE AGENCY'.

Lunar Pathfinder - GNSS Receiver Experiment

Floor Thomas Melman, Michele Scotti (SpacePNT SA), Richard Swinden, Javier Ventura-Traveset, Brice Dellandrea

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

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