Title: **ESA's Nextgen Lunar Laser Retroreflector with Pointing Actuators for NASA's CP11 Mission**

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Abstract: Since 1969 Apollo and Luna missions deployed Laser Retroreflector Arrays (LRAs) of Cube Corner Retroreflectors (CCRs) on the Moon. Thanks to Lunar Laser Ranging (LLR) by ILRS high precision distance measurements of the Moon have been performed. LLR science includes precision tests of General Relativity (GR), study of the internal structure of the Moon and its ephemerides. Over the past 55 years LLR capabilities of ground stations have significantly improved and nowadays lunar LRAs dominate the LLR error budget due to the lunar librations, which result from the eccentricity and inclination of the Moon orbit [1,2]. For this reason we developed MoonLIGHT (Moon Laser Instrumentation for General relativity / Geophysics High-accuracy Tests), a nextgen single, large CCR of 100 diameter, of solid uncoated fused silica, unaffected by lunar librations [1,2]. The MoonLIGHT field of view is about 15 degrees to be pointed to Earth within a few degrees. Since NASA-CLPS landers do not guarantee this accurate pointing, INFN-LNF proposed to ESA the MoonLIGHT Pointing Actuator (MPAc) instrument. ESA selected it for development and signed with NASA an MoU to launch MPAc to the Reiner Gamma swirl with the 3rd mission granted by NASA to Intuitive Machines (IM) [3], currently foreseen in 2025. MPAc will perform two perpendicular rotations to point MoonLIGHT to Earth. The 1st flight model of MoonLIGHT+MPAc was qualified, delivered and accepted by ESA, NASA, IM in 2023 and is in storage in Houston at IM. The 2nd flight model of MoonLIGHT+MPAc has been qualified, delivered and accepted by ESA in September 2024. The research products of MoonLIGHT are [1,2] on astrophysical and geophysical sciences.
Astrophysical Sciences. Deployment of MoonLIGHTs will support, on the LLR space segment, an improvement up to a factor 100 of several tests of GR and relativistic gravity: Weak and Strong Equivalence Principle (WEP/SEP), Gdot/G, Geodetic precession, Yukawa deviations from Newtonian gravity. LLR also allows to set constraints on new theories beyond GR, like: Spacetime torsion [4], f(R) gravity [5], Nonminimally coupled gravity [6], Lorentz-invariance violations.
Geophysics topics. MoonLIGHTs will support improved studies of inertia moments, tides, CMB (Core Mantle Boundary), fluid and solid Core, librations.
For LLR data analysis we use PEP (Planetary Ephemeris Program), a software developed and maintained since the 1960s by the Harvard-Smithsonian Center for Astrophysics (CfA), MA, USA.

**References**

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