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Three lunar laser ranging mission in 2023-2024 by NASA, ESA and CNSA for precision test of general relativity

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More than 50 years ago, Apollo and Luna missions placed five Laser Retroreflector Arrays (LRAs) of Cube Corner Retroreflectors (CCRs) on the surface of the Moon. Through a technique known as Lunar Laser Ranging (LLR), it has been possible to perform high accuracy/precision measurements of the Earth-Moon distance by firing short laser pulses from ground Laser Ranging Stations to these LRAs on the Moon, and measuring their two-way times of flight. LLR outputs include accurate tests of General Relativity, information on the composition of the Moon, its ephemerides and its internal structure, and geocentric positions and motions of ground Laser Ranging Stations.

Since 1969, ground Laser Ranging Stations performances have significantly improved, and currently the lunar LRAs of CCRs represent the main limitation to the achievement of more accurate/precise measurements. The main problem that affects the Apollo and Lunokhod LRAs consists of the lunar librations, that result from the eccentricity of the Moon's orbit around the Earth. For this reason, the Moon Laser Instrumentation for General relativity and geophysics/geodesy High accuracy Tests (MoonLIGHT) program was started at the Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali di Frascati (INFN-LNF). The aim of the program is designing the next generation of lunar retroreflectors, prototyping, manufacturing and qualifying them for the Moon's environment, shifting from a multi-scatterer LRA of small CCRs to a single large 100 mm CCR, named MoonLIGHT, unaffected by lunar librations. MoonLIGHT is twinned to its US counterpart, Next Generation Laser Retroreflector (NGLR), led by University of Maryland, College Park (UMD).

On account of the fact that the industry of landers could not guarantee an accurate pointing of the device towards the Earth, the INFN proposed the MoonLIGHT Pointing Actuator (MPAc) project to ESA in 2018. In 2019, ESA chose MPAc (and another instrument) among 135 eligible scientific project proposals. In 2021, ESA agreed with NASA to launch MPAc to the Reiner Gamma crater, with a Commercial Lunar Payload Services (CLPS) mission, which is part of the Artemis program. Also in 2021, NASA chose Intuitive Machines (IM) as the company that will develop and manufacture the commercial lander where MPAc will be integrated and confirmed its flight for April 2024. NGLR will fly as well in 2024, without its own Pointing Actuator, on board of another CLPS mission, operated by Firefly, towards the Mare Crisium.

In response to the "Announcement of Opportunities for Scientific Payloads onboard Chang'E-6 Mission" issued by CNSA (Chinese National Space Administration) in April 2019, we proposed two laser retroreflector instruments in order to perform precision tests of General Relativity (GR) and precision studies of the lunar interior and of selenodesy. There instruments are: MoonLIGHT, the single, large reflector of 100 mm optical aperture; and INRRI (INstrument for landing-Roving laser Retroreflector Investigations), a miniature array of eight 12.7 mm diameter reflector, already flown on NASA's InSight Mars lander in 2018 and Perseverance rover in 2020.

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