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First campaigns and future developments in the LUNA Moon analog facility

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The current renaissance in lunar exploration, driven by space agencies as well as the private sector, requires suitable test and training facilities on Earth to proceed in a safe and sustainable manner. To address this need, DLR and ESA have opened the Moon analogue facility LUNA in Cologne, Germany, in September 2024. We will provide an overview of LUNA and report on first campaigns, which already included usage by universities, national space agencies, and the private sector.

At the heart of LUNA is a 700 m² regolith hall, filled with Mare simulant EAC-1A to 60 cm depth. With black walls, a preliminary sun simulator allowing to simulate illumination at the lunar south polar region, geologically relevant rocks, an Argonaut lunar lander mock-up, two 3U-rovers that might carry individual instruments, and a future gravity offloading, LUNA simulates the lunar surface and allows to test the operations of instruments and experiments on the Moon as well as train operations for robotic and crewed lunar missions. A dedicated ground segment permits commanding and telemetry and data exchange under mission-like conditions. Further outfitting by elements both within (e.g. a ramp to simulate slopes of at least up to 40 deg) and outside of LUNA (e.g. Flexhab habitat, EDEN-LUNA greenhouse) is ongoing.

The deep floor area (DFA), with a regolith depth of up to 3 m over an area of approximately 135m² and two sloping walls with angles of 25° and 40°, allows for testing geophysical exploration methods as well as drilling and sampling techniques. The initial outfitting of the DFA includes two buried metal reference targets for ground-penetrating radar (GPR), as well as a small simulated lava tunnel at the bottom, constructed from concrete and expanded foam sheets. Additionally, PMMA (aka Plexiglas™) is used to simulate the elastic and dielectric contrasts between regolith and ice, which is of special interest in exploration of the lunar South Pole, and emplaced to mimic both a thin ice horizon as well as distributed veins of ice (reticular chaotic cryostructure, formed by 1000 PMMA discs). A fiber-optic cable, including fibers for distributed temperature sensing (DTS),

distributed acoustic sensing (DAS), and an engineered fiber, has been buried throughout the hall to be used for background data, and a broad-band seismometer has been installed permanently in LUNA. Several seismic reference measurements as well as a GPR test have been conducted to characterize the LUNA hall and environment.

The EAC-1A simulant has been characterized in terms of elastic, electric and thermal properties, e.g. seismic wave velocities and attenuation from resonant column tests, dielectric permittivity and loss tangent, and thermal conductivity. We show in how far these parameters match the values for actual lunar regolith. We will also report on first test campaigns, e.g. regarding geophones and the engineered DAS fibre, GPR, and rover navigation.