LUNA Moon Analog Facility

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Simulation and Testing in a Moon Analog Environment

The DLR team and the European Space Agency (ESA) are currently developing and will later jointly operate the LUNA analog facility in Cologne, Germany, which is scheduled to be built and outfitted in 2023/2024.

LUNA is a logical complement and diversification of the global capabilities for preparing future lunar missions. For the first time, an analog in-door facility is provided a dedicated facility for operational and technical simulation of lunar surface activities of relevant size for humans and robots, which will simultaneously be integrated into the real operational environment of DLR and ESA for the ISS and into the research topics of DLR institutes and potential partners. It complements existing facilities at the Cologne-Porz site and will position the state of North Rhine-Westphalia and Germany on the global map for lunar activities and make them clearly visible. With its worldwide unique infrastructure, LUNA will enable simulations of astronautical and astronautical-robotic lunar operations.

LUNA facility (VR model)

Artist's view of a LUNA surface operation with a rover

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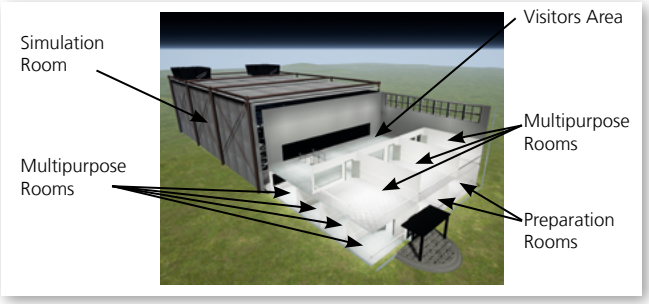
1. Elements of the LUNA ecosystem

The LUNA facility will support the development, testing and simulation of new tools and equipment as well as new operational concepts for future human missions to the Moon and later to Mars.
The LUNA facility is highly integrated into the DLR and ESA infrastructure and profits from experiences and expertise of various institutes and centers.
The facility contains a regolith hall, a technology center and is connected to the European Astronaut Centre (EAC), the Microgravity User Support Center (MUSC) and the German Space Operations Center (GSOC).



LUNA floor plan with layout of the different rooms

1.1 The Regolith Hall

The 60 cm high, 750 m2 regolith area will be equipped with a suspension unit, allowing astronauts as well as equipment to be suspended to one sixth of their terrestrial weight. Moon suits will be provided to allow realistic astronautic excursions. An adjustable tilting table covered with regolith will also be available to test the climbing capabilities of rovers and astronauts as they work around different sized rocks and other obstacles as they would do on the Moon. The regolith area will also contain a mock-up of a lunar lander and a rover, which can be used in simulations of astronautic surface activities.
A Sun simulator will ensure that the different lighting conditions in the various moon regions can be mimiced.
Parts of the hall are designed as deep floor area, where the regolith depths is increased to 3 m, which allows for example drilling experiments and also the heating and cooling of the regolith material.
Also for seismic experiments, provisions have been take to permanently record the seismic background signals within the hall.

1.2 The Technology Center

The hall is accompanied by a technology center, which will offer even more features for reseachers: A dust lab will enable research with different specific kinds of regolith, especially with very fine grain sizes. Various methods allow regolith sinter experiments and other material science studies, either directly inside the LUNA facility or in an adjacent institute's laboratory.
A virtual reality studio will be included to allow research on augmented reality usage for training and operations. This studio can be directly used for LUNA related studies, but also as a multipurpose facility hosting a greenscreen and various video equipment.
The technology center also provides a mechanical and electrical workshop as well as the supply of various technical gasses, which might be needed for the different experiments.
Also a visitor room with a real moon rock displayed there is planned to inform public about the past and upcoming lunar adventures.

1.3 External attachments

Next to the actual LUNA hall and the technology center, there willl be various external attachments. It is planned to provide a moon habitat, which should be attached to the building's outer shell. This module will provide habitation and working capabilities. Here, astronauts will be able to prepare for lunar surface operations like collecting rock samples, don their surface suits, or evaluate samples that they have retrieved from the simulated Moon surface.
In addition, a smart energy module will be attached, that allows generation, conversion, storage, reconversion, supply and overall management of energy provision and usage. Energy will be generated by solar panels and transformed into hydrogen. This will be stored in tanks and, upon request, in fuel cells converted into electrical energy. In the first instance, this energy will be used to power the habitat with a view to potentially powering the entire LUNA facility at a later date.
After its return from Antarctica and a complete remake in Bremen, EDEN-ISS (**https://eden-iss.net/index.php/category/gallery/**) will come to LUNA and will as EDEN LUNA research opportunities as an almost fully autonomous greenhouse to grow and harvest salad greens, fruits or vegetables.

2. Research Possibilities

Artificial signal delays and limited insight into ongoing activities in LUNA will be used to simulate the latency and lack of direct line of sight as would be experienced when astronauts are operating systems and experiments on the Moon surface or on Mars.

In LUNA, researchers and developers – together with teams from other domains – will be able to test their equipment, validate their operational concepts, and develop new ways of solving issues that come with long-term stays on the Moon. These include questions around energy supply, crew transport and general logistic requirements, such as how to produce materials for extended crew habitation, how to prepare for potential emergency situations and many more.

DLR and ESA intend to run LUNA as an open platform, allowing researchers and developers from all over the world to jointly develop the technology and operations necessary for a safe and sustainable return to the Moon's surface.
The LUNA facility and those experiments and technical demonstrations performed within it will be overseen by DLR and ESA operator personnel. From control rooms either inside the facility itself, next door at EAC, or remotely from DLR in Oberpfaffenhofen, the LUNA operations personnel will monitor and control simulations or test campaigns.

	Testing of geological-seismic processes for characterizing regolith properties, In-Situ resource usage, development of mining and winning methods, mapping and storage of rock deposits, methods of biological and chemical analysis of soil samples, projecting and builing of lunar habitats
	Energy generation, convertion, storage, provision and recovery, food cropping/harvesting/provisioning, validation of closed loop cycles for air, water, wastewater, food, waste, clothing, protection / cleaning / care / maintenance of equipment on the lunar surface, impact of the presence of people on the lunar surface
	Development of new work methods and tools for astronauts to work under lunar conditions, dust chamber, Gravity 1/6 g of the Earth's gravity, light conditions, temperature conditions, radiation conditions, transport of objects, surface mobility, cleaning techniques (e.g. from moon dust), habitat exit scenarios, testing of a surface-suit, validation of rescue scenarios, human robotic partnership
	Testing of new semi-automated medical procedures, augmented reality in emergency medical care scenarios, analysis methods for radiation-, UV- and microbiological stress and development and validation of countermeasures such as practicality of a radiation protection vest, validation of effects on the immune and health status of the crew, development of new physical exercise protocols and devices
	Remote control of experiments, telerobotic control of rovers (with signal time delays), building IT infrastructure around and on the moon, transferring high data rates (forward and return links), logistics
	Development, testing and validation of new mission operating concepts and tools (EGS-CC), simulation of new (distributed) operations concepts

LUNA utilization cases

3. Control from anywhere in the World

It is foreseen that subsystems and equipment to be tested will be able to be controlled on-site or from anywhere in the world in order to allow external entities to remotely join in on simulations or test campaigns. Since we expect and plan for LUNA to be used for anything from very simple equipment tests to highly complex scenarios and multi-day campaigns with several subsystem operators distributed around the world, the services provided for LUNA will encompass:

- The provision of detailed descriptions of equipment available in LUNA and its capabilities (including a visit of LUNA and on-site consultancy)
- Consultancy on the feasibility of test objectives and scenario composition including:
  - Topic of research/test
  - Duration of test
  - Number of test runs
  - Exclusive use of LUNA or opportunity to combine with other objectives/tests
  - Technical and personnel support functions required
  - Location of equipment-related support personnel, e.g. on-site or remote support
  - Technical interfaces, e.g. equipment, hard- and software, provision of monitoring and control system functionalities and their incorporation into the overall LUNA operations system, simulation or test data processing, data provision, storage and archiving, and required time for setting up and implementing these technical interfaces.
- Development of test choreography and possibly integration with other tests (LUNA "on-orbit" operations timeline development)
- Development of required procedures for ground operators and LUNA astronaut crew
- Implementation of all interfaces, their testing and validation
- Provision of operations/operations support by experienced LUNA "flight" and ground controllers.

Additional services such as LUNA-related astronaut training, related medical services and the use of infrastructure available at the European Astronaut Centre or DLR's :envihab, can be provided and implemented as required.

Lunar Living Concept: Artemis Base Camp concept (NASA) with a lander, a rover and some lunar infrastructure (Artist View, Credit: NASA)