LUWEX

Summary

Validation of Lunar Water Extraction and Purification Technologies for In-Situ Propellant and Consumables Production

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Funded by the European Union

The LUWEX project is an initiative focused on developing and validating technologies for extracting, purifying and monitoring lunar water, and advancing In-Situ Resource Utilization (ISRU) to support sustainable space exploration. Water is a vital resource for human space exploration, serving as a consumable for astronauts, radiation shielding, and, when split into hydrogen and oxygen, a crucial component of rocket fuel. By harnessing lunar water resources, LUWEX seeks to reduce reliance on Earth-bound supplies, paving the way for sustainable long-duration missions.

The project employs an integrated test setup to simulate lunar conditions, using icy lunar dust simulants in a thermal-vacuum chamber to validate its process chain. This approach aims to elevate the Technology Readiness Level (TRL) of the system, supporting future European-led space exploration missions.

Key project outcomes include the development of a lunar water extraction and purification system, validating ISRU technologies, and promoting interdisciplinary collaboration across academia, industry, and institutional research. By advancing Europe’s capabilities in space exploration, LUWEX contributes to the global effort to make space missions more viable, affordable, and sustainable.

LUWEX

Validation of Lunar Water Extraction and Purification Technologies for In-Situ Propellant and Consumables Production

Content


credits: pexels.com

WATER IN SPACE EXPLORATION

"Finding water is often a good pathway for finding life itself, or at least understanding where some of the chemical building blocks of life might have come from."

Dr James Carpenter, European Space Agency

IN-SITU RESOURCE UTILISATION (ISRU)

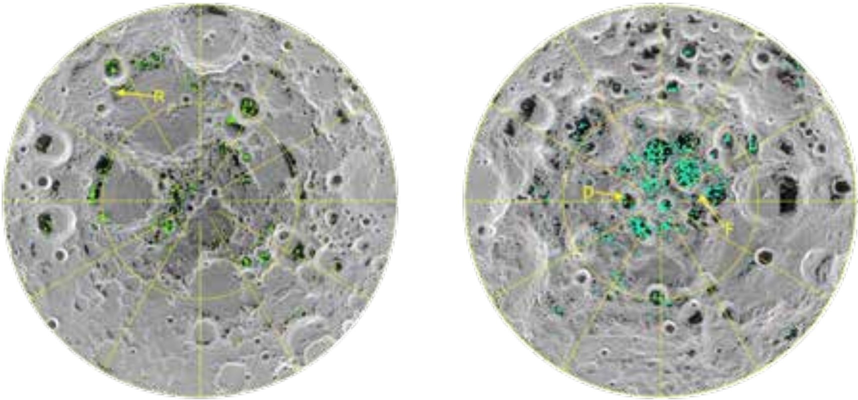
Long-term human lunar exploration relies on the development of In-Situ Resource Utilisation (ISRU) technologies, which are designed to reduce reliance on Earth-based supplies by harnessing local resources. These include water, volatiles, metals, rocks, regolith, and atmospheric components, as well as waste materials like discarded hardware and human-generated refuse. By producing essential products directly in situ, ISRU significantly lowers mission mass, cost, and risk.

When fully integrated into mission architectures, ISRU systems enable the production of materials and resources needed for both robotic and human activities, paving the way for a sustainable presence on the Moon, Mars, and beyond. These technologies play a crucial role in advancing autonomous exploration and reducing the logistical challenges associated with long-duration space missions.

ISRU systems greatly decrease the required resupply from Earth and will enable humanity to establish a permanent presence on the Moon, on Mars and in other locations of the solar system.

PODCAST EPISODE
ABOUT IN-SITU RESOURCE UTILISATION

WATER ON THE MOON

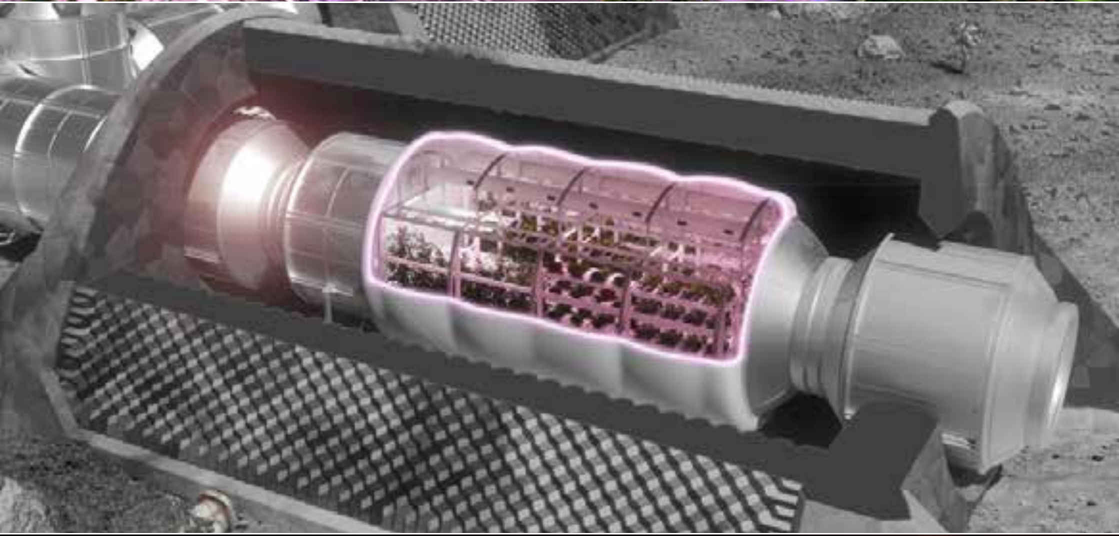


The distribution of surface ice at the Moon's south pole (left) and north pole (right), as detected by NASA's Moon Mineralogy Mapper instrument, which flew aboard India's Chandrayaan-1 spacecraft. Blue represents ice locations, and the gray scale corresponds to surface temperature, with darker gray representing colder areas and lighter shades indicating warmer ones.
credits: NASA

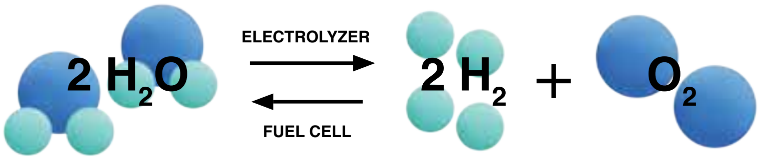
The most important resource that can be extracted from the lunar surface is the water ice present in the permanently shadowed and near polar craters of the Moon [1]. Recent developments in lunar water prospecting indicate that its presence might be not limited to permanently shadowed regions and might include both sunlit areas [2] as well as micro cold traps [3].

Water present on the lunar surface is currently the focus of the planetary science and space technology communities. Not only it can provide information about the formation of the Solar System, but also represents an opportunity to make space travel more inexpensive, opening the way for commercial activities on and around the Moon.

Of all the natural resources, water is, by far, the most versatile and most needed resource in space exploration.



WATER AS A RESOURCE



Lunar water offers immense potential for sustainable lunar exploration. Through electrolysis, water can also be split into hydrogen and oxygen.

Life Support Systems and Agriculture: Oxygen can be used for life support systems for astronauts, meeting critical human spaceflight needs. Additionally, sustainable food production can be achieved on the lunar surface by utilizing lunar water. Hydroponic systems can be adapted to lunar conditions in order to cultivate plants in a controlled environment, addressing crew dietary needs while boosting psychological well-being [4,5].

Radiation Protection: Lunar water can also fulfil the radiation protection needs of future habitats. By lining habitats with water, astronauts can benefit from its ability to absorb harmful radiation, including cosmic rays and solar particles, especially beneficial during solar storms or prolonged exposure to space radiation [6].

Fuel and Energy: Oxygen and hydrogen can be used in fuel cells to generate electricity, while liquid hydrogen and liquid oxygen form a highly efficient spacecraft propellant, enabling cost-effective travel to Mars and beyond [7].

Top: EDEN ISS Greenhouse, credits: DLR

Middle: Greenhouse concept for the Moon and Mars, credits: LIQUIFER

Bottom: Rocket exhaust from burning the rocket's propellant, credits: pexels.com

PODCAST EPISODE
ABOUT WATER IN THE UNIVERSE

Website
luwex.space

HARNESSING WATER ON THE MOON

"We don't know yet how the water ice regolith mixture behaves, when we warm it up, and how the water vapour forms where it flows. There is a lot of fundamental research questions involved in this project. And that makes it really exciting because it's a combination of fundamental physics, and engineering."

Dr Paul Zabel, German Aerospace Center

PROJECT OBJECTIVES

- **Development of Water Extraction, Purification, and Quality Monitoring Technologies**:
  This in-situ raw water process chain is essential for ensuring the availability of consumable water for astronauts and for generating hydrogen and oxygen for propulsion.

- **Design and Manufacture of an Integrated Experimental Setup**:
  To accurately simulate lunar conditions, this setup provided a controlled environment to test the operational capabilities of the developed technologies, using a lunar dust-ice simulant.

- **Validation of In-Situ Raw Water Technologies in a Laboratory Environment:**
  The validation phase involved testing the developed technologies in a laboratory setting that mimics the lunar environment.

- **Advancing European Excellence in Space Exploration**:
  By developing and validating ISRU technologies, LUWEX enhances the scientific and technological capabilities of Europe in the field of space exploration.

- **Improving Interdisciplinary Collaboration and Leveraging Synergies**:
  The project fostered collaboration across various sectors, including industry, academia, and institutional research. This interdisciplinary approach leveraged synergies and promoted the sharing of knowledge and expertise, ultimately contributing to the success and impact of the project.

These objectives align with international and European space exploration goals. By achieving these objectives, the LUWEX project provides innovative solutions for sustainable and affordable long-duration space missions, significantly impacting future European-led space exploration and enhancing the competitiveness of the European space sector [8].

PROJECT RESULTS

Project execution (2022-2024)

- Laboratory breadboard and validation of a lunar water extraction, purification and quality monitoring.
- Lunar raw water simulant and a lunar ice-dust simulant for scientific experiments.
- Provision of scientific data from the technology validation experiments.

EXPECTED OUTCOMES

Medium-term effects (2024+)

- Lunar water extractor and purifier as contribution to European-led space exploration of the Moon.
- Validation of the ISRU water process chain in an analogue environment.
- Simulants, data and strategies for science and leading-edge technology developments in Europe.

EXPECTED IMPACT

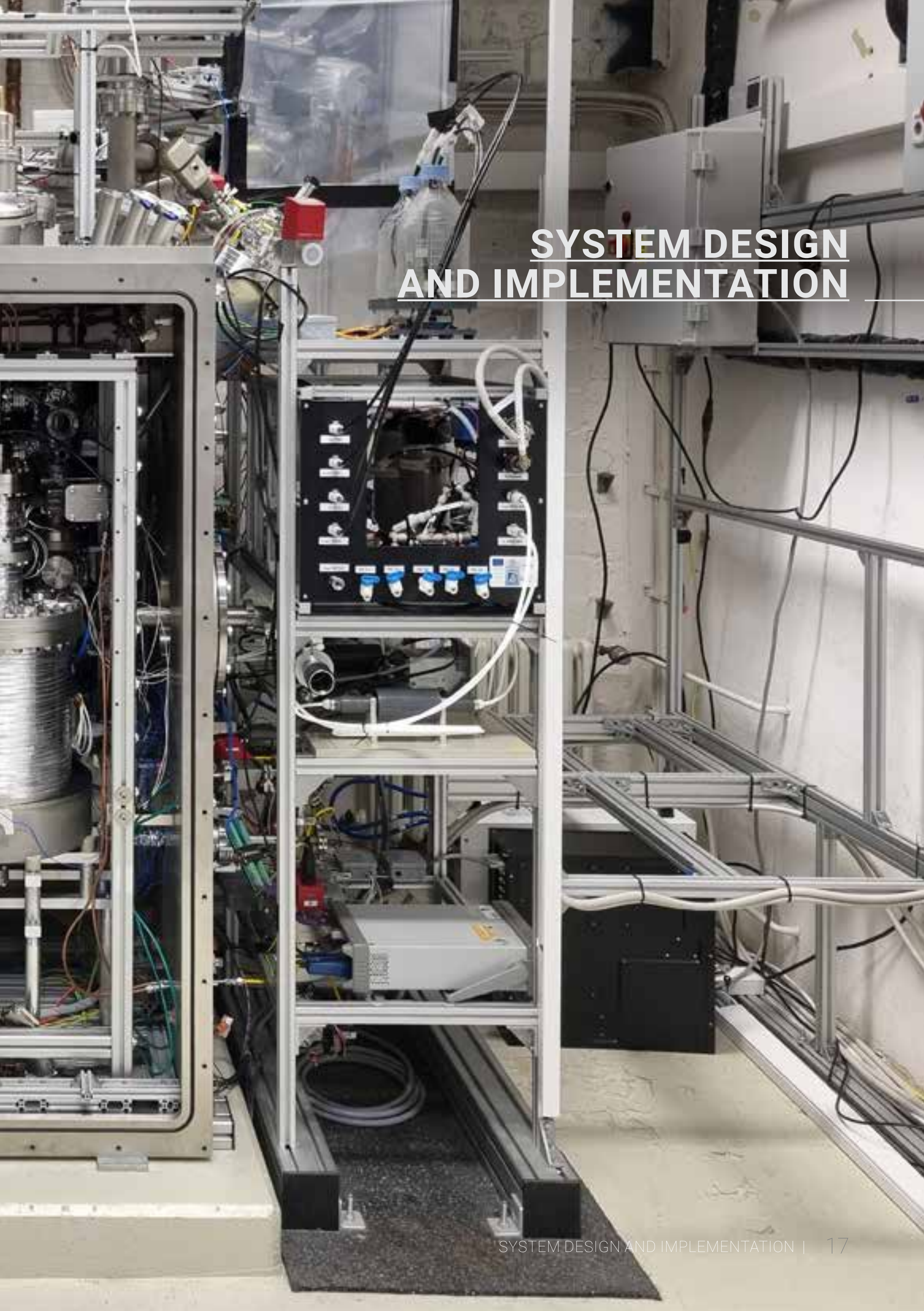
Long-term effects (2030)

- Demonstration on the Moon of European capabilities to exploit lunar water ice deposits.
- European, disruptive ISRU technologies enabling new innovations and business cases.
- Enabling excellent science activities in Europe for lunar exploration and science.

"Project LUWEX is very unique, because we are testing on a large scale to extract water from the lunar regolith simulant."

Dr Christopher Kreuzig, Technische Universität Braunschweig

The whole setup of the LUWEX experimental system

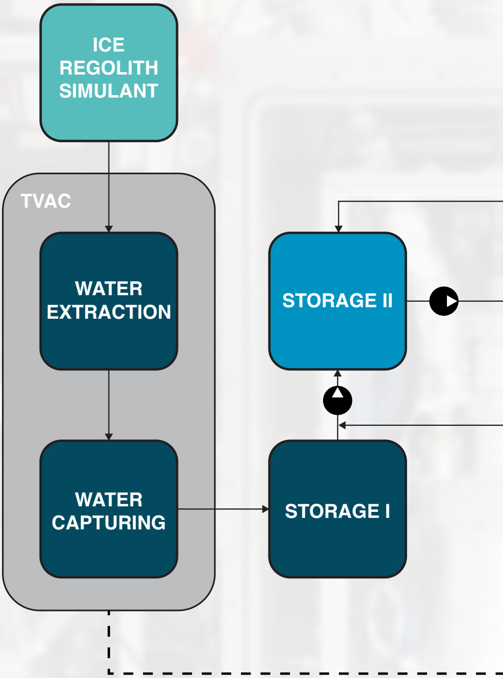


SYSTEM DESIGN AND IMPLEMENTATION

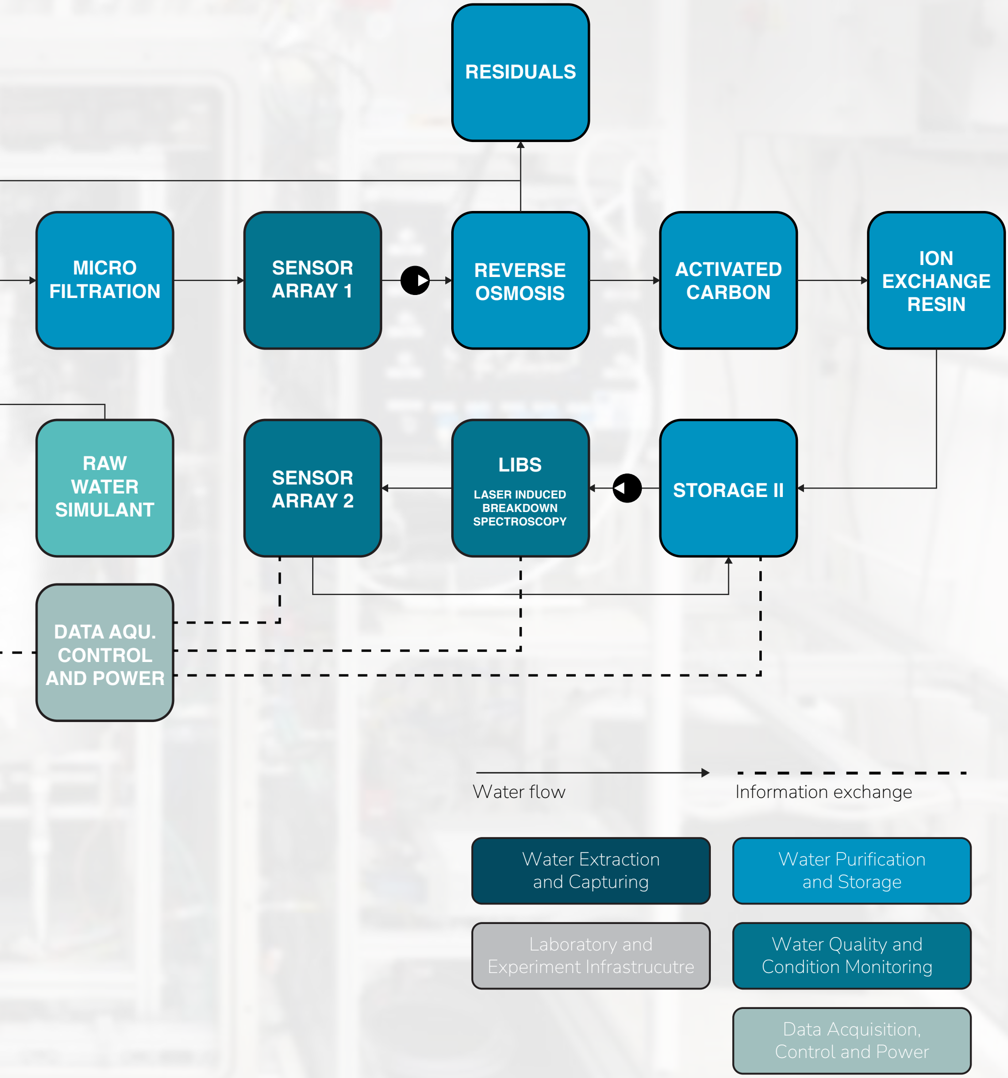
SYSTEM OVERVIEW

The LUWEX experimental system replicates a future lunar water extraction process, integrating the following subsystems:

- **Water Extraction and Capturing Subsystem (WECS)**: Housed in the Thermal Vacuum Chamber (TVAC), this subsystem processes ice-regolith simulants to extract water.
- **Water Purification Subsystem (WPS)**: Purifies extracted water through multiple stages.
- **Water Quality and Condition Monitoring Subsystem (WQCM)**: Ensures water meets required standards during processing.
- **Data Acquisition, Control, and Power Subsystem**: Centrally manages system operation and data collection.



The figure above illustrates the material flow across the system. The extracted water is captured and stored in Storage I, a vacuum-rated tank connected to the TVAC. It is then transferred to Storage II, where its quantity is measured. The water is subsequently processed through purification stages, with quality continuously monitored. This integrated setup replicates the critical steps required for lunar water utilisation.



System block diagram of all subsystems of the LUWEX experimental setup.
Dashed arrows indicate signalinterfaces.
Solid arrows indicate water (solid, liquid or gaseous state) flow.

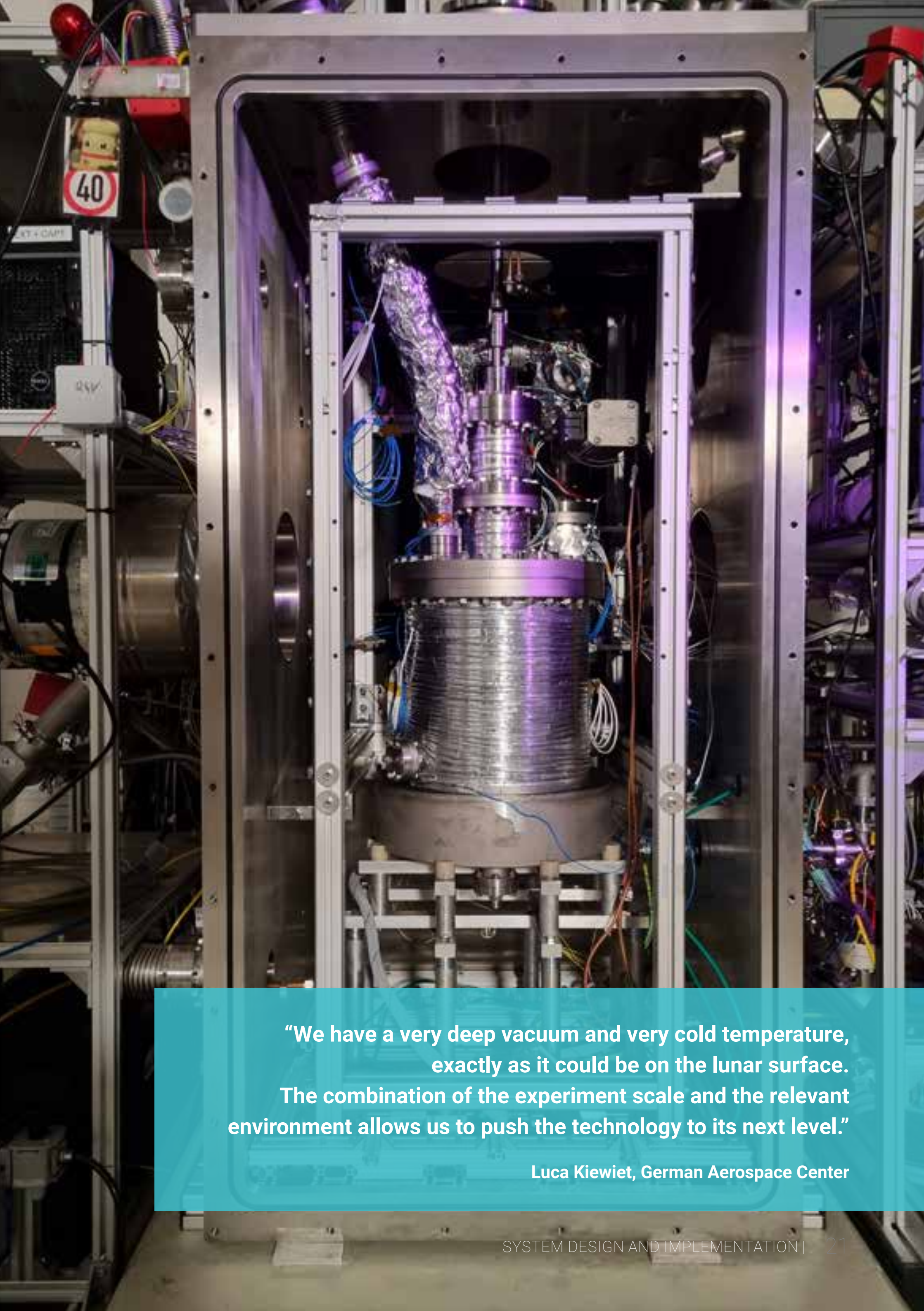
SIMULATING LUNAR CONDITIONS: THERMAL VACUUM CHAMBER (TVAC)

The Thermal Vacuum Chamber at Comet Physics Laboratory, TU Braunschweig, is a state-of-the-art facility originally developed for comet research. It replicates lunar surface conditions, enabling experiments with dust-ice mixtures at temperatures as low as -170°C under vacuum conditions.

The Water Extraction and Capturing Subsystem was placed inside the Thermal Vacuum Chamber. To replicate lunar conditions, part of the TVAC is evacuated to 5×10^{-6} mbar using a turbo-molecular pump and fore pump, then cooled to 110K with dual liquid-nitrogen cooling systems.

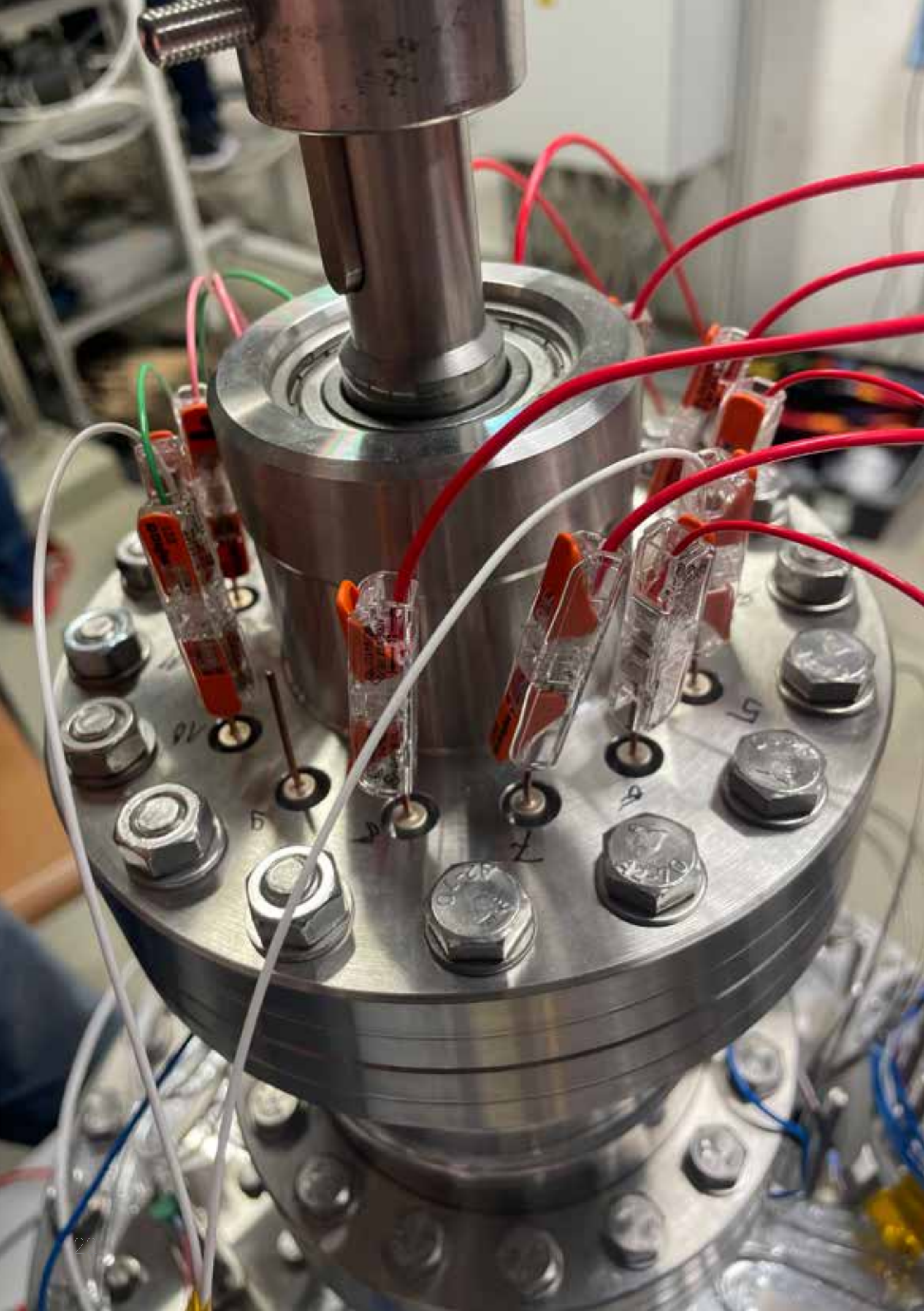
The crucible containing the ice-regolith simulant is placed directly on the primary cooling system, ensuring conduction-based cooling. This setup closely mimics the thermal conditions experienced by a crucible in direct contact with the lunar surface, making it an invaluable tool for simulating and studying water extraction processes on the Moon.

Left: The Moon, credits: NASA
Right: Thermal Vacuum Chamber setup



"We have a very deep vacuum and very cold temperature, exactly as it could be on the lunar surface. The combination of the experiment scale and the relevant environment allows us to push the technology to its next level."

Luca Kiewiet, German Aerospace Center



WATER EXTRACTION AND CAPTURING SUBSYSTEM (WECS)

The Water Extraction and Capturing Subsystem (WECS) is designed to extract water vapour from the icy regolith simulant by sublimation and then liquefying it for storage and purification. The system achieves this through two key components: extraction subsystem and capturing subsystem.

Extraction Subsystem: The extraction subsystem sublimates the ice in the icy regolith simulant to generate water vapour. Due to the regolith's low thermal conductivity, a stirring mechanism is implemented to enhance heat distribution. Heating rods, mounted at varying radii, rotate to ensure uniform heating and prevent unheated gaps in the simulant. This stirring also facilitates the escape of water vapour from dried-out regolith.

Capturing Subsystem: The capturing subsystem consists of a cold trap and a liquefaction chamber. The cold trap provides a surface cold enough for water vapour to freeze. Once sufficient ice accumulates, internal heaters are activated to sublimate the ice layer, causing it to drop into the liquefaction chamber.
The liquefaction chamber is sealed off, and heaters melt the collected ice into liquid water. The water is then transferred to Storage I, located outside the vacuum chamber, for subsequent transport to the purification system.

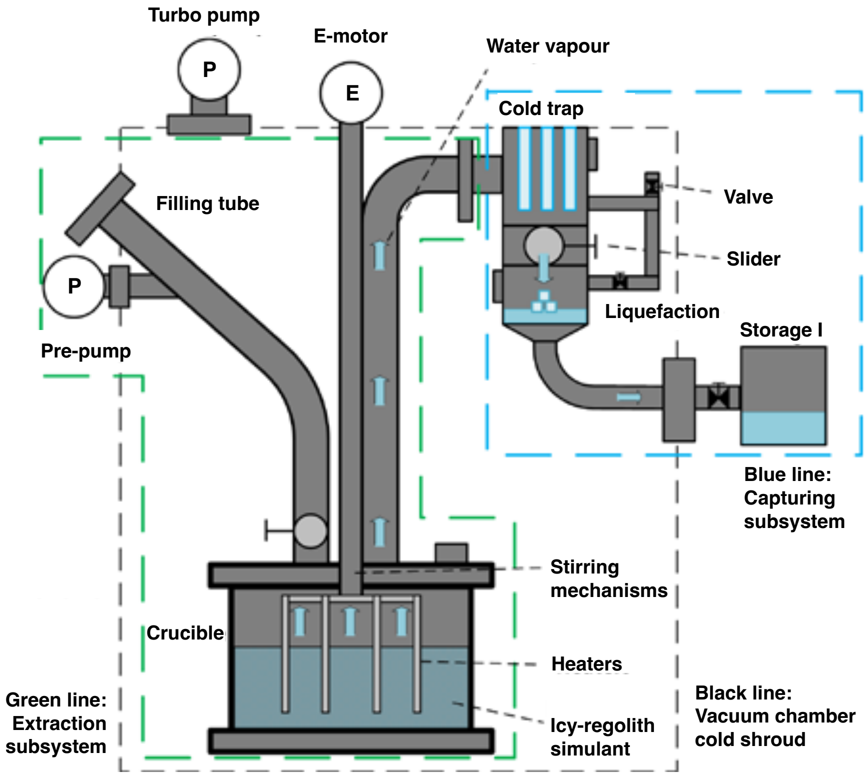
The low thermal conductivity of lunar regolith poses challenges for heating and sublimating ice. To address this, a stirring mechanism was implemented: heating rods were rotated to evenly distribute the heat and facilitate the release of water vapour.

Left: Vacuum-rated power and mechanical feedthrough on top of the crucible

PODCAST EPISODE
ABOUT WATER EXTRACTION

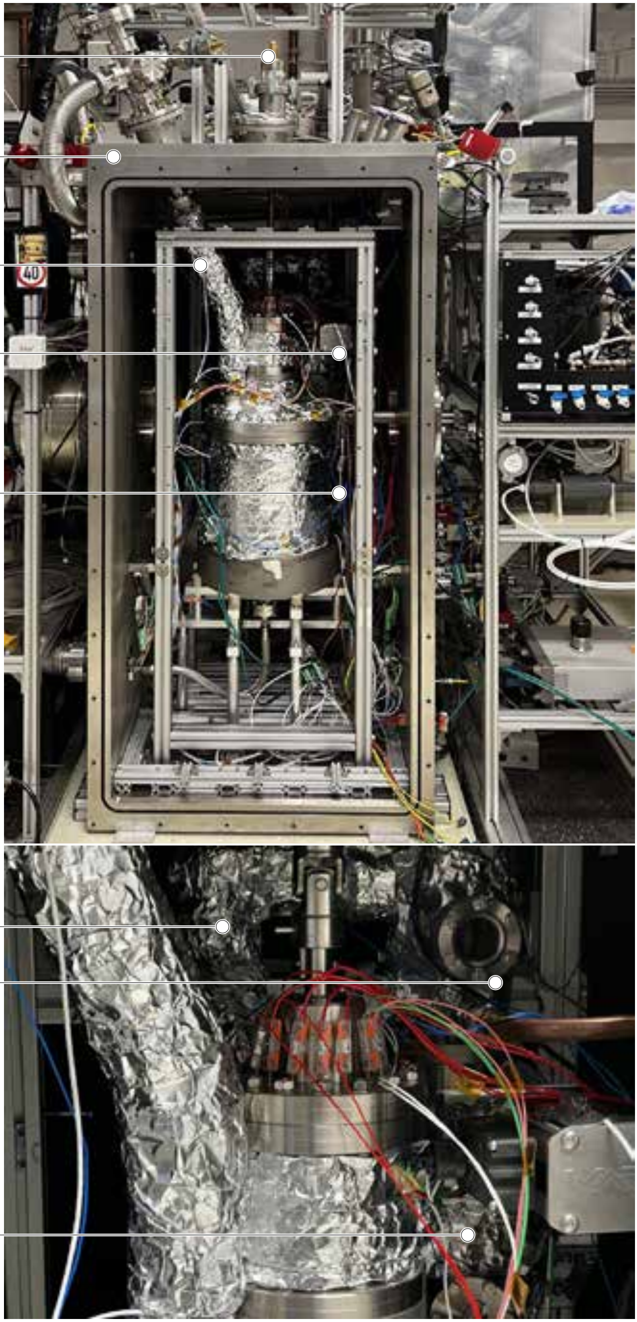
The figure below presents a schematic overview of the entire Water Extraction and Capturing Subsystem, as well as the boundaries of the vacuum chamber in which it is placed, and the tube used for filling the crucible with the icy regolith simulant. The different coloured lines show the lines between the different subsystems and their boundaries.

The figure on the right shows how the assembled Water Extraction and Capturing Subsystem looks inside the Thermal Vacuum Chamber after integration.



Top: Schematic overview of the WECS inside and partially outside the TVAC. The parts inside the green dashed line are the extraction subsystem, and the components encircled by the blue dashed line are the capturing subsystem.

Right: The assembled WECS Water Extraction and Capturing Subsystem inside the TVAC.


Motor connection
TVAC
Filling tube
Slider
Emptying tube
Water vapour tube
Cold trap
Liquefaction chamber

“I do believe that our huge effort of finding water in places where it is hard to find brings extreme value to human space exploration. It is also linked to how we decide to handle our footprint as human beings in the future.”

Giorgio Boscheri, Thales Alenia Space

WATER PURIFICATION SUBSYSTEM (WPS)

The Water Purification Subsystem is designed to treat the water from the Water Extraction and Capturing Subsystem, which contains various contaminants. Its goal is to meet the strict water quality requirements for water electrolysis, which are more demanding than those for potable water.

The purification methods were selected to minimise consumables, achieve high water recovery, and ensure scalability for lunar missions. Contaminants are categorised into particulates, organics, and inorganics, with different removal technologies for each:

- **Particulate removal**: A microfiltration membrane removes particles larger than 0.45 µm, primarily lunar dust. Smaller particles are not expected to reach the WPS.
- **Organic removal**: Activated carbon (AC) is used, with steam regeneration considered to reduce consumables. Methanol, a critical organic contaminant, is expected to be mostly removed in the WECS, but if higher levels are detected, additional methods for total organic carbon (TOC) reduction will be explored.
- **Inorganic removal**: Reverse osmosis (RO) is used for the efficient removal of inorganic materials, particularly ammonia, without consumables. RO concentrate is recirculated, minimising wastewater generation. Ion exchange resins provide final polishing to meet purity requirements for technical water.

This approach ensures that the Water Purification Subsystem is both effective and efficient in preparing water for electrolysis while minimising system waste and maintaining scalability for future lunar applications.

Left: WPS (black rack insert) integrated in a rack on the right-hand side of the TVAC. Storage II (glass bottles) on top of the rack.

PODCAST EPISODE
ABOUT WATER PURIFICATION

WATER QUALITY AND CONDITION MONITORING SUBSYSTEM (WQCM)

The Water Quality and Monitoring Subsystem (WQCM) is designed for real-time monitoring of water quality in the system, positioned both upstream and downstream of the Water Purification Subsystem. It consists of two sensor arrays and a Laser Induced Breakdown Spectroscopy (LIBS) system.

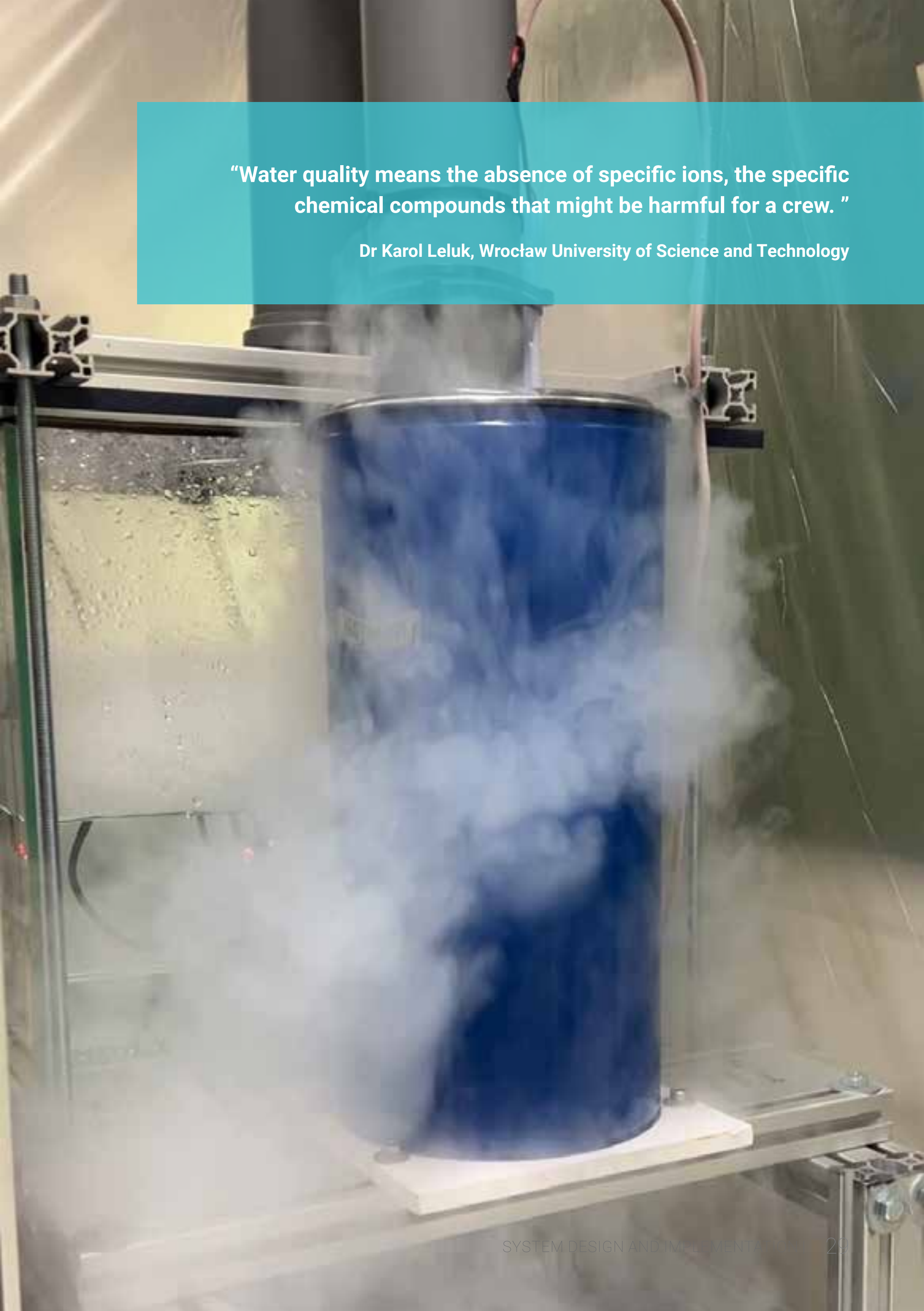
Sensor Arrays: Each sensor array includes a conductivity probe, a turbidity probe, and a pH sensor. The upstream array monitors the water before purification, while the downstream array monitors the water after purification. Conductivity probes measure ion concentration, turbidity probes assess suspended particles, and pH sensors verify conductivity readings and detect potential impurities during water production.

Laser Induced Breakdown Spectroscopy: The LIBS system uses a laser to create plasma from the water sample, which emits light that is analysed to determine the composition. This allows for the detection of multiple pollutants without the need for numerous specific sensors, and it can be performed in line without harming the water.

Additional Testing: In addition to the in-line monitoring, sample ports on the WPS allow water to be collected for laboratory testing, which provides higher accuracy for validating the in-line measurements and gaining additional insights.

This multi-tiered monitoring system ensures continuous, accurate assessment of water quality, detecting any anomalies in the purification process and supporting further analysis when needed.

Right: Production of micrometer-sized ice particles.



“Water quality means the absence of specific ions, the specific chemical compounds that might be harmful for a crew. ”

Dr Karol Leluk, Wrocław University of Science and Technology

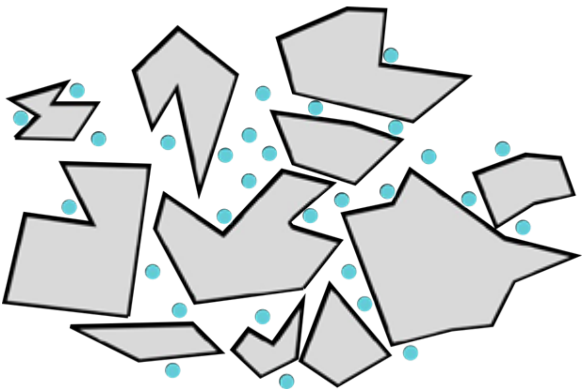

The icy regolith simulant

PROJECT OUTCOMES

ICY REGOLITH SIMULANT

A dust-ice simulant was created by mixing synthetic lunar regolith with self-produced granular water ice. The ice was produced using a specialised ice machine, which atomised distilled water into a fine mist, which was then frozen in liquid nitrogen, to form spherical ice particles with a median radius of 3.3 micrometres. The resulting ice particles, resembling powdered sugar, were separated from the nitrogen and stored for later use. These ice particles were then mixed with lunar regolith simulant.

To create the icy regolith simulant, the lunar regolith simulant was first dried to remove moisture. The regolith simulant, a mixture of 75% anorthosite and 25% basalt, was then cooled to below -160°C before being mixed with the granular water ice. The ice was added in small quantities, ensuring an even distribution in the regolith. The resulting simulant was prepared for further testing and analysis under lunar-like conditions.



A graphical representation of the unfused discrete icy-regolith. The high porosity of this specific sample means that even though ice is added, the thermal conductivity remains low.

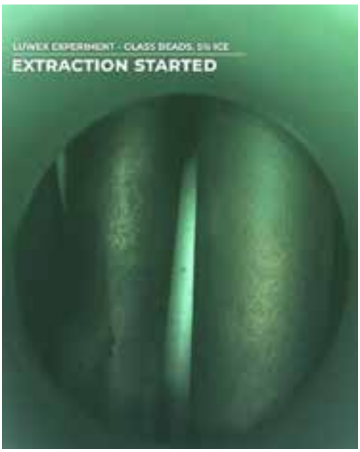
The icy regolith simulant just after mixing in the ice particles. This process is done under cryogenic temperatures.

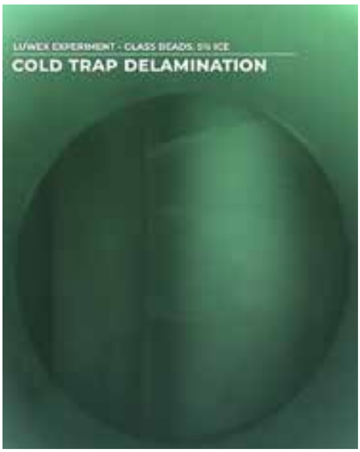
FUNCTIONAL VERIFICATION AND TRL ADVANCEMENT

Each subsystem of the LUWEX project was individually tested for performance and functionality before being integrated into the overall experimental setup. Once integrated, the complete LUWEX system was tested as a unified water process chain, resembling a full-scale lunar water extraction system.

The water extraction and capturing subsystems were tested within a cryogenically cooled vacuum chamber. Given the low temperatures, vacuum conditions, and the use of high-fidelity lunar regolith simulants, these subsystems were deemed sufficiently exposed to lunar-like conditions, supporting initial steps towards a TRL 5 achievement. The remaining subsystems were tested in a controlled laboratory environment, reaching TRL 4.

Upon completion of the system-level test campaign, the fully integrated LUWEX system achieved TRL 4, demonstrating the successful validation of the lunar water value chain—from extraction to the production of clean water.

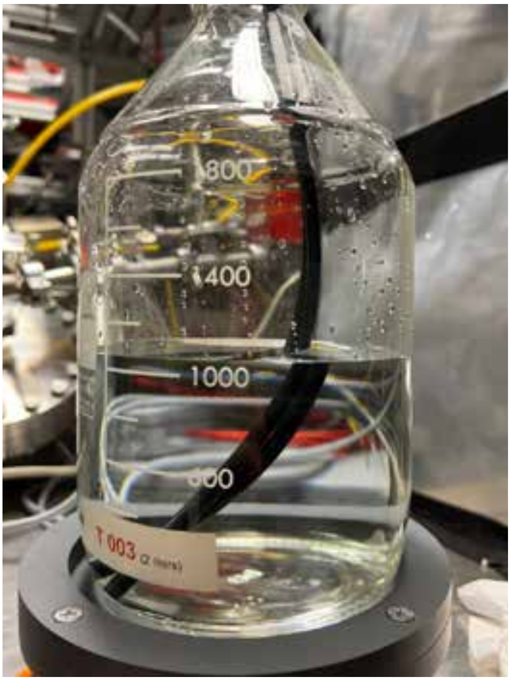




View into the cold trap showing the copper cold fingers for water vapour capturing.
Left: Original state before starting the water extraction.
Right: An ice layer several millimeters thick has formed during the water extraction process.

CAD drawing of the cold trap.

Polluted raw water directly after the water extraction and capturing process.



Clean water as a result after purifying the raw water.

“We have to look at what we really need, what we can take from the location we are at, and how we can always keep resources in a loop because it is very cumbersome to source materials, and goods we need for the everyday life. We really need to take good care of what we have.”

Dr Barbara Imhof, LIQUIFER Systems Group

RESULTS

Scientific results:

1. The project validated a complete ISRU water process chain in a laboratory environment up to TRL 4.

2. The project developed and validated a process for water extraction and capture from icy lunar regolith in a relevant environment, achieving TRL 4/5.

3. The project developed and validated a system for purifying water polluted with typical lunar volatiles in a laboratory environment up to TRL 4.

4. A raw water simulant mimicking lunar water with potential contaminants was developed during the project.

5. An icy regolith simulant, mimicking a possible mixture of ice and lunar dust, along with the process to prepare it, was developed during the project.

Dissemination and Exploitation results:

6. The project conducted a feasibility study to identify which of the developed technologies are best suited for further development toward a lunar surface exploration mission.

7. A market analysis was carried out to explore how the project's technologies could be transferred to terrestrial applications.

8. The project was showcased at six conferences through posters or presentations.

9. Two peer-reviewed articles had already been published at the time of the brochure's publication, with two more in preparation.

Outreach results:

10. The project website (www.luwex.space) was launched at the beginning of the project and has been regularly updated with news, project developments, published materials, and more.

11. A podcast titled "Water Beyond Earth" was created during the project, featuring seven episodes with team members and external experts.

12. A videocast series was also developed, with five episodes published, highlighting interviews with team members.

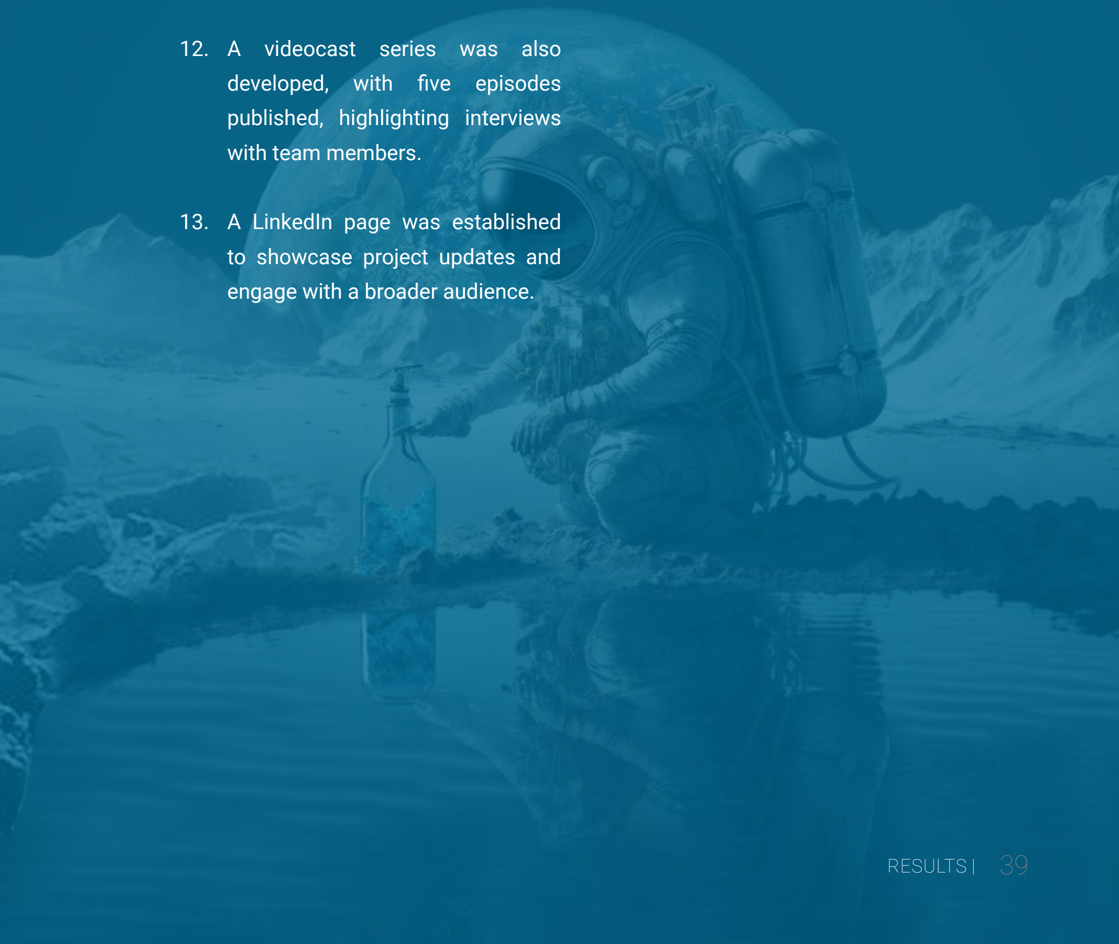
13. A LinkedIn page was established to showcase project updates and engage with a broader audience.

Educational results:

14. During the project, four students completed their Master's theses on scientific questions arising from the research activities.

15. Six students contributed to project-related tasks and supported the experimental campaign.

16. One PhD candidate is incorporating selected scientific results into their dissertation.



Earthrise, taken on December 24, 1968,
by Apollo 8 astronaut William Anders
credit: NASA

ADAPTABILITY TO FUTURE MISSIONS

"I think one of the things we need to be thinking about is environmental justice and sustainability. We have not done many favours to planet Earth, and we need to think about what we could potentially do to others. We should be considering what we have a right to do and what we want to do there."

Dr Jill Stuart, London School of Economics and Political Science

European Large Logistic Lander (EL3)
credit: ESA

APPLICATION TO FUTURE SPACE MISSIONS

LUWEX was developed from the beginning with the aim of integration into future European-led space exploration missions, from its demonstration phase to the final utilisation one.

The harsh lunar environment, characterised by extreme temperatures, vacuum conditions, and abrasive dust, poses significant challenges for any technology. Demonstrating water extraction and purification technologies in this setting provides a rigorous testbed, validating the robustness and efficiency of these systems. This not only mitigates risks for future missions but also drives innovation in engineering solutions tailored to extraterrestrial conditions.

The technology demonstration phase relies on the availability of the European Large Logistics Lander, or Argonaut. Integrating a demonstrator for lunar water extraction and purification technologies within the Argonaut payload envelope represents a transformative step in space exploration and resource utilisation. The Argonaut project, designed to deliver cargo and logistics to the Moon, provides an ideal platform for integrating the water extraction demonstrator. The lander's capabilities can support the deployment, operation, and monitoring of the extraction and purification systems. A modular design for the demonstrator ensures flexibility and adaptability, allowing it to be a seamless addition to the Argonaut mission.

Initial missions can be used to demonstrate single LUWEX subsystems and processes, like water sublimation and freezing, raw water ice liquefaction, icy-regolith management, and water purification. Later missions can then include a scaled-down version of the complete system.

Looking ahead, the ability to extract and purify water on the Moon is fundamental to establishing a sustained human presence. The system's design includes considerations for integration with habitat life support systems and power grids, making it suitable for both short-term outposts and long-term bases. By leveraging LUWEX technology, lunar bases can reduce their dependence on Earth-based resupply missions, thus lowering mission costs and increasing self-sufficiency.

TERRESTRIAL APPLICATIONS

Water Purification Module

The LUWEX purification module meets essential water needs through advanced filtration, such as hydrophobic nanostructured membranes and solar-powered desalination, making it adaptable for areas with limited access to clean water. As water demand rises, LUWEX's capability to purify diverse water sources—from municipal to heavily contaminated—positions it as a crucial solution.

Water Quality Monitoring Module

The LUWEX monitoring module detects contaminants, including pharmaceuticals, to meet modern regulatory demands for safe water. By offering real-time data on water quality, it enables timely interventions, enhancing public health through early detection of harmful substances.

Storage Module

LUWEX's storage module provides effective water storage, keeping purified water safe and accessible over time. This is particularly valuable in areas prone to seasonal water shortages or in disaster response, ensuring clean water availability when it's needed most.

Drying-out river bed
credit: pexels.com

Addressing Global Water Issues

With increasing water, LUWEX's modular system offers scalable solutions that are crucial for addressing global water shortages. Its flexible design allows implementation in both large-scale and localised setups, helping to bridge the growing gap in freshwater availability.

Integration with Existing Technologies

The LUWEX modules integrate seamlessly with existing water treatment systems, enhancing performance and extending equipment lifespan. This adaptability makes it practical and effective for both upgrades and standalone installations.

Pilot Projects and Future Development

Pilot projects in diverse settings, such as regions facing water scarcity or high pollution, will demonstrate LUWEX's capabilities. Collaborations with local stakeholders will ensure the technology adapts to specific regional needs, maximising its impact on global water sustainability.

In our podcast miniseries “Water Beyond Earth” we explore the captivating world of lunar water extraction and purification. Join us on our voyage into space, as we focus on LUWEX, the groundbreaking endeavour for Lunar Water Extraction and Purification Technologies.

Throughout this podcast miniseries, we will explore the significance of water in space exploration and showcase cutting-edge technologies that enable this possibility. We immerse ourselves in the visionary goals of LUWEX and experience the complex process of harnessing water from the lunar regolith.

Guest experts and scientists leading the way guide us through innovative engineering solutions and the concept of in-situ resource utilisation.

WATER BEYOND EARTH
PODCAST

WATER BEYOND EARTH PODCAST

PODCAST EPISODES

E01: Harnessing Water on the Moon

Dr Paul Zabel from the DLR Institute of Space Systems, an aerospace engineer with a deep passion for space exploration, talks about the project LUWEX, and the importance and potential of water in lunar and space exploration.

E02: Water in the Universe

Dr James Carpenter, a physicist specialising in space astrophysics and planetary science from the European Space Agency talks about into the captivating topic of water within the universe.

E03: In-Situ Resource Utilisation

Dr Angel Abbud-Madrid, the Director of the Center for Space Resources at the Colorado School of Mines, shares insights on In-Situ Resource Utilisation (ISRU) in the realm of space exploration.

E04: Water Extraction

In this episode, our focus goes deeper into the technical aspects of the LUWEX project. Together with **Luca Kiewiet**, a researcher from the German Aerospace Center (DLR) in Bremen, and **Christopher Kreuzig**, a researcher at the Technische Universität Braunschweig in the Institute of Geophysics and Extraterrestrial Physics, we explore the process of extracting water from regolith.

E05: Water Purification

In this episode we investigate the crucial role of water in lunar and space exploration, discussing water processing and purification strategies. Our guests, **Giorgio Boscheri**, a Space Engineer from Thales Alenia Space Italia, and **Dr Anna Jurga** and **Dr Karol Leluk**, researchers from the Faculty of Environmental Engineering at Wrocław University of Science and Technology, bring diverse perspectives to the discussion. We examine environmental engineering in space systems, including methods, spacecraft-specific technologies, and prospects for Moon-based agriculture.

E06: Establishing a Moon Base

In this episode, we explore how humans might live and work on the Moon. With our guests, **Dr Jill Stuart**, an expert in the politics, ethics, and law of outer space exploration and exploitation from the London School of Economics and Political Science, and **Dr Barbara Imhof**, co-founder, Managing Partner, and co-owner of LIQUIFER, we explore the challenges of space architecture, learn about legal considerations, and discuss ethical dilemmas in human space exploration.

E07: Role of Private Companies in Lunar Exploration

In this episode, we're joined by **Mikołaj Podgórski**, representing Scanway Space, a company specialising in advanced optical instruments for space, Earth Observation technologies, camera systems, and optoelectronics. We talk about laser-based quality control systems for Earth and space, along with lessons learned and technology transfer. We also discuss the essential role that private companies play in the future of lunar and space exploration.











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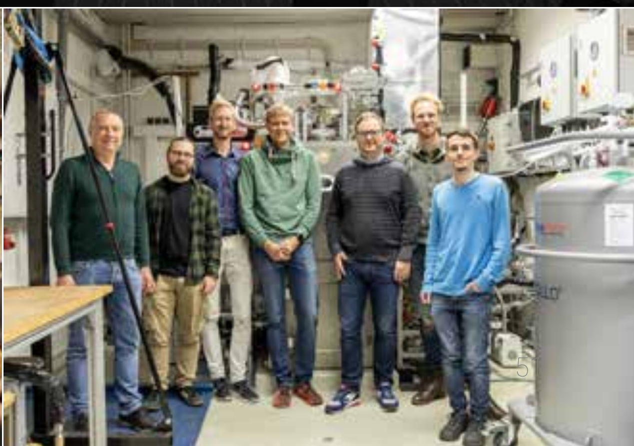

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Germany

DLR (Institute of Space Systems, Bremen site) is appointed as the coordinator due to its experience in managing space projects of different budgets and scopes, which includes EU projects with a technology development, manufacturing and assembly component (e.g. EDEN ISS). Furthermore, DLR's experience in systems engineering, especially in utilising Concurrent Engineering for a fast and consistent design of the validation test setup, will reduce the duration of the design phase significantly. DLR also has extensive knowledge in ISRU system development with its research group located at its Bremen site, including laboratory and workshop space.

LIQUIFER Systems Group

Austria

LIQUIFER Systems Group is a leading partner in configuration architecture, designing space habitats and space analogue tests having access to suitable facilities. In the LUWEX project, LIQUIFER is responsible for the definition of system requirements, the harmonisation of the overall requirement set as well as the coherence of the interface. Additionally, due to their experience in public engagement activities (multiple video documentaries for ESA, diverse websites for projects and companies, and podcasts for radio stations and internet platforms), LIQUIFER is responsible for strategy and materials for dissemination, exploitation and communication of the LUWEX project.

Technische Universität Braunschweig,

Germany

Institute of Geophysics and Extraterrestrial Physics
The TU Braunschweig LUWEX group has year-long experience in studying granular matter under planetary conditions, both experimentally and using computers. These conditions comprise low to high gravity levels, vacuum, or rarefied gas environments and very low to very high temperatures. The responsibilities of the TU Braunschweig in the LUWEX project range from a thorough study of the state-of-the-art lunar-regolith description to the provision of a large thermal vacuum chamber in which the water extraction experiments shall be carried out.

Scanway S.A.

Poland

Scanway's role in the LUWEX project is to provide a part of the water quality control system. The equipment delivered by the company is based on the LIBS (Laser-Induced Breakdown Spectroscopy) measurement technique, which allows the surface chemical composition of the material – in this case water, to be determined. Such a facility will be able to tell if the extracted water stays within the desired limits of the selected quality standards.

Wroclaw University of Science and Technology

Poland

Faculty of Environmental Engineering
The Wroclaw University for Science and Technology (WUST) LUWEX team has a strong educational and academic research background in terrestrial water supply, sewage, water treatment, microbiology, environmental protection, waste management and water quality. In the LUWEX project, WUST's responsibilities are water quality and condition monitoring and the investigation of the potential terrestrial applications.

Thales Alenia Space

Italy

Thales Alenia Space has responsibilities at the system and subsystem level. At the system level, the company is responsible for technical coordination and roadmapping toward future space applications. At the subsystem level, it is responsible for the development and testing of the extracted raw water purification stage.

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> **"Inspiration, maybe arguably, is the most powerful resource that space can give us and can bring to all so that we continue pushing for further exploration beyond our planet."**
>
> **Dr Angel Abbud-Madrid, Colorado School of Mines**

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German Aerospace Center

Technische Universität Braunschweig

LIQUIFER SYSTEMS GROUP

ThalesAlenia Space
a Thales / Leonardo company

Wrocław University of Science and Technology

Scanway space