www.dlr.de/irs

HIGHLIGHTS 2024

YEARLY STATUS REPORT
PLANETARY INFRASTRUCTURES

DLR

A novel icy lunar regolith simulant developed for the EU-funded project: LUWEX. LUWEX is the first project to demonstrate large-scale water extraction and purification in a realistic lunar environment.

THE YEAR 2024

2024 - a year of success and change.

After Germany has signed the Artemis Accords in 2023, the year 2024 could only be an exciting follow-up year and guess what – 2024 had indeed a lot to offer. New projects were launched, targets were exceeded, and significant improvements were made.

Our water extraction project LUWEX had its official testing phase and extracted over 2 l of water from lunar icy regolith. The project was concluded with a final presentation in December.
The new project BIOLOOPS entered its Assembly, Integration, and Test (AIT) phase. Here the multi-purpose experimental cultivation facility was designed to study the dynamics of hydroponic plant growth, using pre-treated urine as the main nutrient source for the plants.

Key highlight of 2024 was clearly the DLR/CSA joint design study of the Lunar Agriculture Module – Ground Test Demonstrator (LAM-GTD), which took place at the DLR's Concurrent Engineering Facility (CEF) in Bremen. Further, the redesign of the Closed-Loop Test Facility inside our laboratory was completed and 2024 was the first year of successful aeroponic growth of leafy greens, fruit vegetables, and herbs. After an intensive refurbishment, incl. new paint/ logo, the EDEN Luna facility arrived back at our institute, ready for the next steps, which will include the integration of new Controlled Environment Agriculture (CEA) subsystems.

Find out what else happened in 2024! We look forward to another year of success and significant milestones.

Stay tuned!

Prof. Dr. Daniel Schubert
Research Cluster Leader –
Planetary Infrastructures

Yearly Status Report 2024

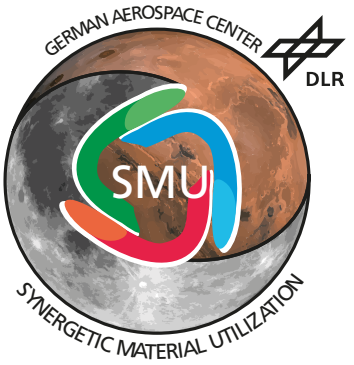
PLANETARY INFRASTRUCTURES

For a successful human exploration strategy, resources such as water, oxygen, food, and also rocket fuel, energy, habitat building materials, and many different types of consumables will need to be generated and adequately recycled within future extra-terrestrial outposts. Combining two approaches, reclamation and recycling, is the key focus of the Planetary Infrastructures research area. The group is administered by the Department of System Analysis Space Segment (SRS) at the DLR Institute of Space Systems in Bremen (Germany). The department operates the Institute's Concurrent Engineering Facility (CEF) as well as the Planetary Infrastructures laboratory, including the Space Habitation Plant Laboratory (EDEN Lab), ISRU Breadboard (SMU Lab), 3D Printing Farm, and former EDEN ISS research greenhouse in Antarctica.

DLR Institute of Space Systems, Bremen (Germany)

THE EDEN INITIATIVE

In 2011, the DLR Institute of Space Systems launched its research initiative called EDEN: Evolution & Design of Environmentally-closed Nutrition-Sources. The research initiative focuses on bio-regenerative life support systems (BLSS), especially greenhouse modules and how these technologies can be integrated in future space habitats. It is the goal of the EDEN team to further advance the latest cultivation technologies and to adjust these developments into space-related applications. Even though present scenarios for future human missions to the Moon and Mars are still several years from coming to fruition, the development of these technologies needs to start today. Only this way will highly-reliable and resource-efficient BLSS be ready for implementation into the mission architecture for humanity's journey to the Moon and Mars.



SYNERGETIC MATERIAL UTILIZATION

The Young Investigator Group Synergetic Material Utilization (SMU) was founded in 2021 after winning a DLR internal competition. The group focuses on the development of technologies for ISRU on the Moon and Mars and how to establish synergies between ISRU and life-support systems (LSS). The group consists of two PhD candidates, several student assistants, and group leader Dr. Paul Zabel. The current research focus is set on three areas: 1) Regolith beneficiation and utilization, 2) in-situ propellant and consumables production, and 3) development of shared ISRU-LSS infrastructures. In the first area, a beneficiation breadboard is under construction to pre-process lunar regolith before utilization. The goal of the second area is to develop a prototype for extracting water from the lunar surface. The third area focuses on a shared water-hydrogen-oxygen infrastructure for a future space habitat. All three areas are of high near-term importance for space exploration and are high priorities in European and international roadmaps.

PLANETARY INFRASTRUCTURES TEAM

PROF. DR. DANIEL SCHUBERT studied at the Technical University of Berlin and has an engineering diploma in industrial engineering with an emphasis on aerospace and production techniques. 2018 he received his doctorate at the University of Bremen. Since December 2023, he holds a professorship at the Technical University of Dresden. In 2011, he initiated the EDEN group at the DLR Institute of Space Systems for technology investigations on Bio-regenerative Life Support Systems and has since served as the team leader of this group.

CLAUDIA PHILPOT is a Diploma Engineer who studied aerospace engineering at the Technical University of Berlin and joined the EDEN Team in 2022. Her expertise as a satellite operations manager in Industry and Research as well as programmatic experience working with ESA on industry-driven ISS utilization supports her role as the Project Manager for EDEN LUNA.

MICHEL FABIEN FRANKE is a systems engineer with experience in the automotive and space sector. As part of the Planetary Infrastructures group, his research focuses on bio-regenerative life support systems (BLSS). Currently, he is working as the project manager for LAM-GTD, while also taking care of subsystem development and configuration management tasks. Before joining the team as a full-time employee in 2023, he also contributed to the department's ISRU-related research.

KUNAL KULKARNI is a PhD candidate in the Synergetic Material Utilization research group and is working on the development of beneficiation technologies for the processing of lunar and Martian regoliths. He holds a M.Sc. in Space Engineering from the Technical University of Berlin. He joined DLR in 2022. His research expertise is in ISRU technologies and the design of space systems.

DR. PAUL ZABEL studied aerospace engineering at the Technical University of Dresden and has a doctorate from the same university. He joined the EDEN team in 2012. Since 2021, he leads the Synergetic Material Utilization group at the DLR Institute of Space Systems. He is the coordinator of the EU-funded project LUWEX. Dr. Zabel is also the deputy manager of the Planetary Infrastructures Laboratory. His research expertise is in ISRU research and innovation and also in life-support systems.

DR. CONRAD ZEIDLER has been a member of the EDEN research team since January 2011. For his industrial engineering diploma at the Technical University of Braunschweig, he specialized on aerospace engineering and has profound knowledge of trade-off analysis techniques (e.g., AHP). He is an expert in simulation methods and control software. Within EDEN, he is responsible for monitoring and controlling the plant growth and environmental parameters.

MARKUS DORN, a horticulture expert with an M.Sc. in plant sciences (University of Natural Resources and Life Sciences, Vienna), joined the team in 2017 to consult on horticultural matters. He has evaluated plant candidates, developed cultivation methods for fruit trees in planetary habitats, and organized the EDEN plant lab. Since 2023, he leads the Planetary Infrastructures lab.

VINCENT VRAKKING studied at the Technical University of Delft in the Netherlands and holds a M.Sc. in aerospace engineering. He began working with the EDEN team on and off in 2012, before joining the team full-time in 2015. Within the EDEN group, he focuses on structure and subsystem design and the development of 3D-printing prototypes.

JESS BUNCHEK is a botanist (B.Sc., Purdue University), agronomist (M.Sc., Penn State University), and PhD candidate in space systems engineering at the University of Bremen. She supported crop production on the International Space Station at NASA's Kennedy Space Center before joining the EDEN team as a DLR-NASA guest scientist in 2020. From 2020 to 2022, she overwintered at Neumayer Station III as the EDEN ISS greenhouse operator. Her research focuses on resource efficiency and the interaction between crops and the astronaut crew.

TOBIAS KORTH studied Aerospace Engineering at the Technical University of Dresden and completed his final thesis with the EDEN group in 2022. After rejoining the team in July 2024 as a subsystem engineer, he is responsible for the development of the Atmosphere Management Systems for the projects EDEN LUNA and LAM-GTD as well as implementing novelties in the EDEN plant cultivation laboratory.

MATEO REJÓN LÓPEZ is a physicist (B.Sc., University of Granada, 2017) and aerospace engineer (M.Sc., Technical University of Delft, 2023). He has extensive experience in In-Situ Resource Utilization, including his work on lunar bricks at ESA's EAC and lead of the ESA-sponsored team at the Over the Dusty Moon Challenge held at the Colorado School of Mines. He joined SMU in March 2024, where he works as project scientist.

CHRISTIAN SCHNORR studied Food Technology at the University of Applied Sciences in Fulda and currently holds a M.Sc. in food processing. He is a guest scientist within the EDEN group and is currently working on his PhD thesis investigating the utilization of inedible biomass from plant cultivation by rearing mealworms (Tenebrio molitor L.), including efficient ingestion, digestion, mass gain, and fiber reduction.

LUCA KIEWIET is a PhD candidate in the Synergetic Material Utilization research group and develops water extraction methods for the Moon and Mars. He holds a 2nd-level Master's degree in Space Systems Engineering from the Politecnico di Torino and a double degree in Space Science and Technology from Luleå University and Université Paul Sabatier Toulouse. He joined DLR in 2021. His expertise is ISRU and space mechanisms.

KYUNGHWAN KIM is a PhD candidate in the EDEN group, developing a Lunar Gravity Simulator to optimize human factors and ergonomics for the Lunar Agriculture Module. A qualified architect (HMONP) in France, he holds an M.Sc. in Space Studies and an M.Arch. in Advanced Computation. His research focuses on space habitats, human factors, and ISRU materials. Kyunghwan joined the EDEN team in 2022 and freelanced in 2023-2024.

TOR BLOMQVIST studied Food Science and Agronomy at the Swedish University of Agricultural Sciences (SLU). Tor is investigating how to implement post-harvest management in space and is now working on the VESTA project. This initiative is aimed at establishing a state-of-the-art R&D infrastructure for closed-loop food production on the Moon and Mars by integrating innovative solutions for post-harvest management and food production.

CHARMAINE NEUFELD studies at the University of British Columbia in Canada. She holds a B.A.Sc in Mechanical Engineering and is currently working on her M.A.Sc. in aerospace combustion. Charmaine was a student team member of the Food Production Team at the CSA (September 2022-2023). Now as a guest engineer at DLR, Charmaine will continue the collaboration work between DLR and CSA.

Arrival of the refurbished EDEN LUNA container at the DLR in Bremen, Germany.

EDEN LUNA

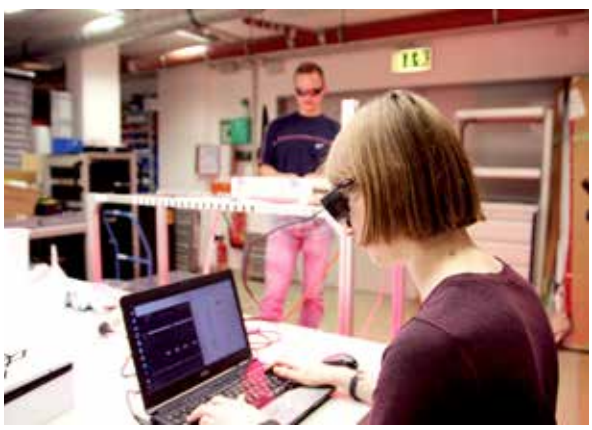
DESIGNS, ANALYSIS, TEST ...
SYSTEM ENGINEERING PAR EXCELLENCE

Throughout the whole year, the team was busy with the re-design of the EDEN facility, clarifying all new and old interfaces with new and old system elements. New technical drawings were created, building and working permissions requested and approved in order to set up the following Assembly, Integration, and Test (AIT) Phase. In August the containers returned from an overall refurbishment and maintenance procedure, which was performed at the manufacturer company CBG GmbH, located near Bremen. Main adjustment is the permanent connection between the two containers. Further the doors were renewed and several adjustments and improvements were conducted inside of the facility. Last but not least, the outside of the facility received a new painting including the new EDEN LUNA logo.
The EDEN LUNA Critical Design Review (CDR) took place from the 22nd to 24th of October 2024. Experts from ESA, the tbd University, and all involved DLR institutes were present during the CDR. From across the Atlantic, the University of Arizona and the University of Guelph supported us very kindly with their invaluable review and feedback.
EDEN LUNA is planned to be attached to the LUNA facility in Cologne by 2026. The main building of the facility LUNA was completed by mid-2024. The inauguration took place on 25th September 2024 together with the ESA Director General J. Aschbacher and Chair of the DLR Executive Board Prof. A. Kaysser-Pyzalla in Cologne.

The EDEN LUNA/ISS Container is back home!

LUNA Hall inauguration ceremony, Cologne, Germany.

EDEN LUNA – Arrival of the refurbished container from CBG Containerbau GmbH.



Testing for the reuse of Heliospectra LEDs in the laboratory at DLR Bremen, Germany.

The EDEN team at the LUNA inauguration ceremony in Cologne.

EDEN LUNA Project Manager, Claudia Philpot, inspecting the refurbishment of the EDEN container


DLR

11

ESA astronaut Matthias Maurer is working on the Moon (LUNA hall, DLR/ESA Cologne)

Cucumber Crop Care by Markus Dorn; small image shows harvested cucumbers, tomatoes and peppers.

LABORATORY UPDATE

FROM SALAD TO SCIENCE AND SENATORIAL SPOTLIGHT

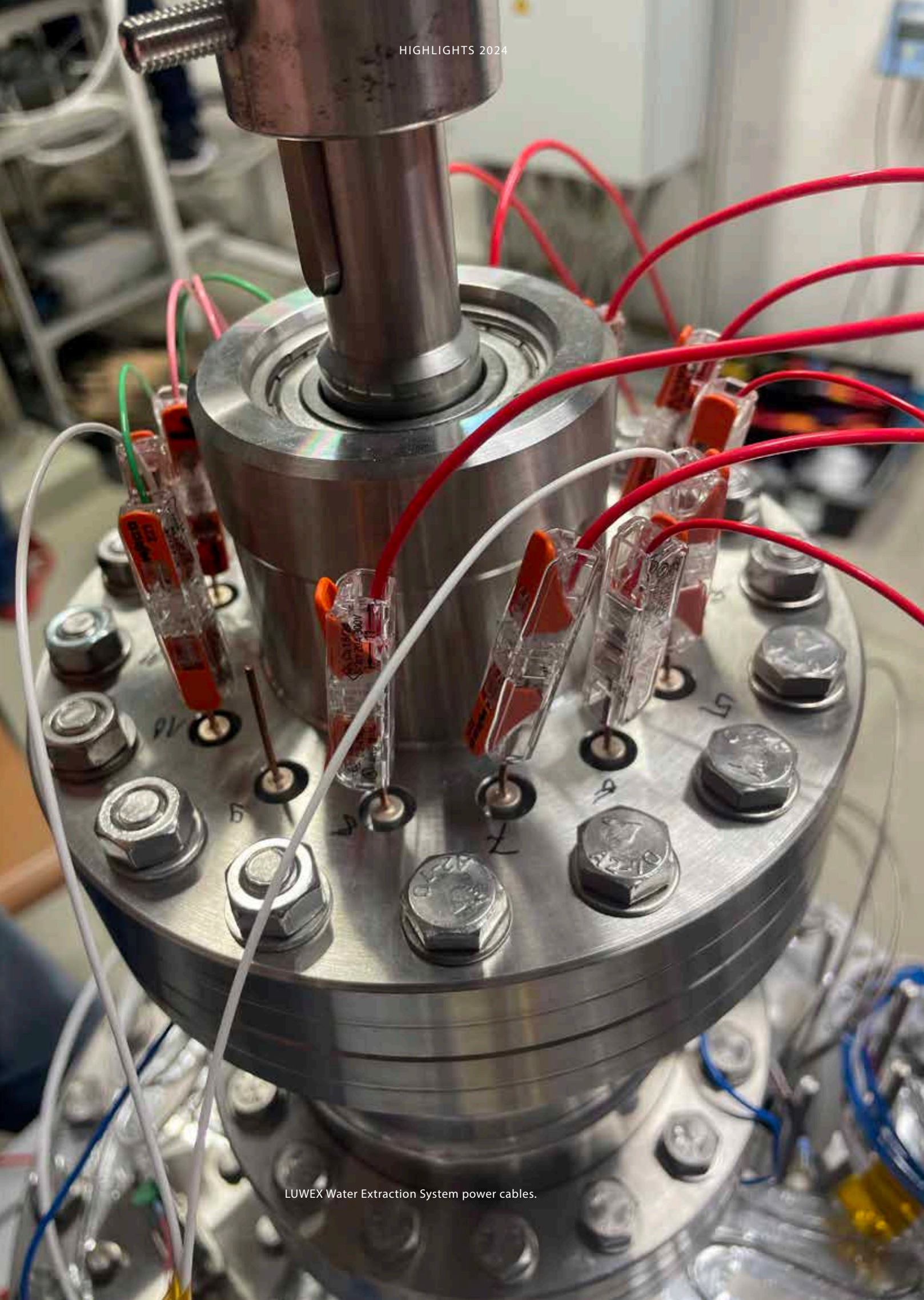
Production-stage cucumbers in high-wire system.

In In 2024, the Planetary Infrastructures laboratory achieved significant milestones in controlled environment agriculture (CEA) technology and In-Situ Resource Utilization (ISRU). The breadboard infrastructure for the aeroponic plant cultivation system marked another year of progress. It completed its first full operational year, with successful aeroponic growth of leaf vegetables, fruiting vegetables, and herbs. A major highlight was the successful implementation of control mechanisms and automation. Developed in collaboration with the Core Avionics department, these improvements increased the efficiency and precision of the plant cultivation systems.

Progress was made with the SMU group's Regolith Beneficiation Test Stand and Water Extraction Unit. Pre-development tests were conducted in preparation for future experiments in the LUWEX project in Braunschweig. The lunar regolith beneficiation testbed underwent a comprehensive experimental campaign in 2024. Currently, a new testbed is under development that will use the same working principle as the laboratory setup, but be more compact with a payload-style architecture to further increase the research fidelity. The regolith simulants also underwent an extensive characterization process focusing on all the mineral phases present within the simulants.

We are excited and fully prepared for the coming year, ready to launch into new technology testing and developments!

Inside the Closed Loop Test Facility: Mixed-cropping approach in small growing racks.



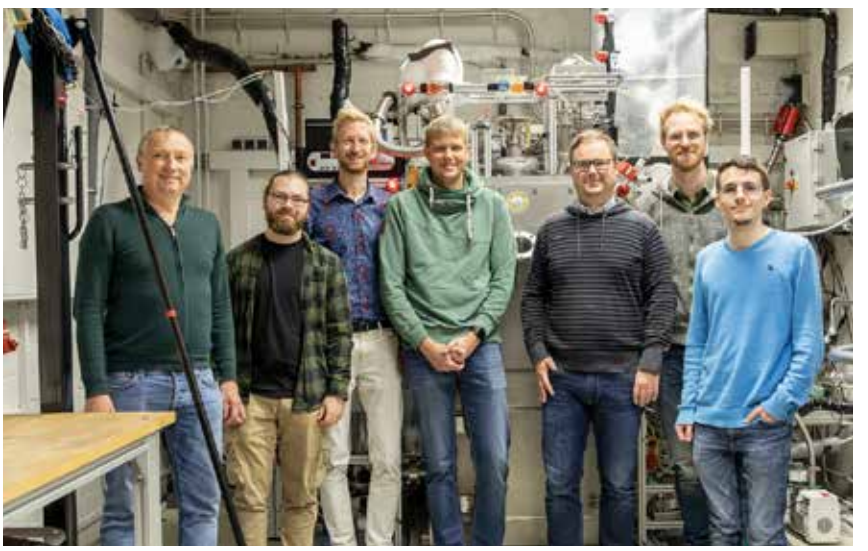
LUWEX Water Extraction System power cables.

LUWEX

WATER FROM THE LUNAR SUBSURFACE FOR SPACE EXPLORATION

As part of the LUWEX research project, the team developed a process to extract and purify water from icy lunar regolith (moon dust), to supply rocket fuel and drinking water for future astronauts stationed on the Moon. This process has now been successfully tested in experiments. Using the thermal vacuum chamber at the CoPhyLab (Comet Physics Laboratory) at TU Braunschweig, the project team combined self-produced ice with synthetic lunar regolith to create a dust-ice simulant. Water was then extracted from this simulant under controlled conditions in the thermal vacuum chamber. The team tested various samples with different proportions of regolith and ice to determine the optimal process parameters for water extraction. The project aimed to maximize water extraction on the Moon while minimizing energy consumption. Key questions included identifying the best temperature and stirring speed for the process. The target of obtaining at least half a liter of water in each test run was surpassed, with nearly 65% of the water from the simulated lunar material successfully extracted and treated. Across multiple experiments, the team recovered a total of more than three liters of clean water.
The LUWEX project officially concluded with a final presentation in December 2024, attended by the EU officer and an external reviewer. During this meeting, the team presented all the results, demonstrating that the technology has progressed well beyond TRL4. Now that the project has ended, the extensive data collected will help identify the most effective methods for water extraction, capturing, and purification, paving the way for sustainable lunar exploration in the future.

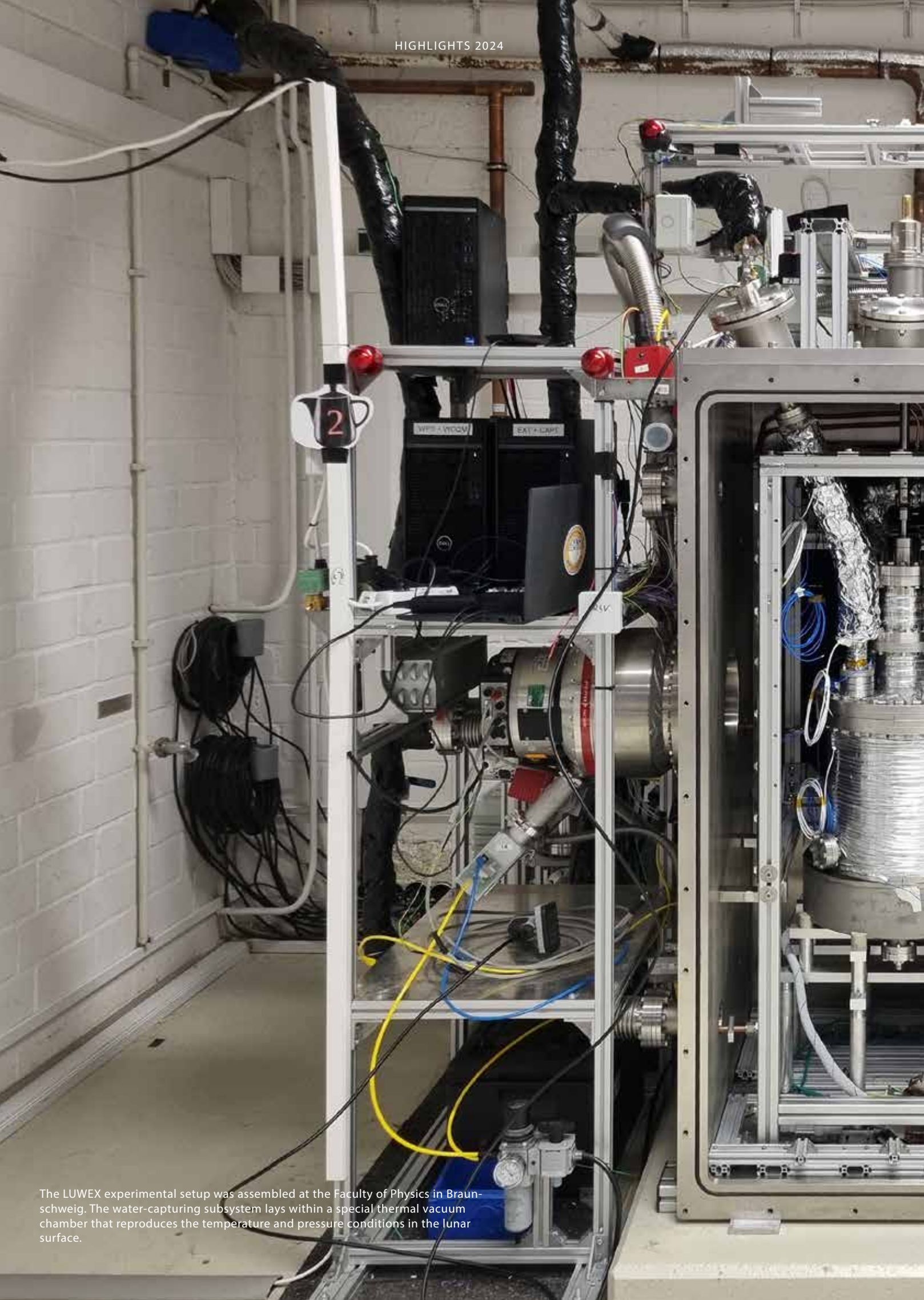
Water after extraction and capturing, before being purified.



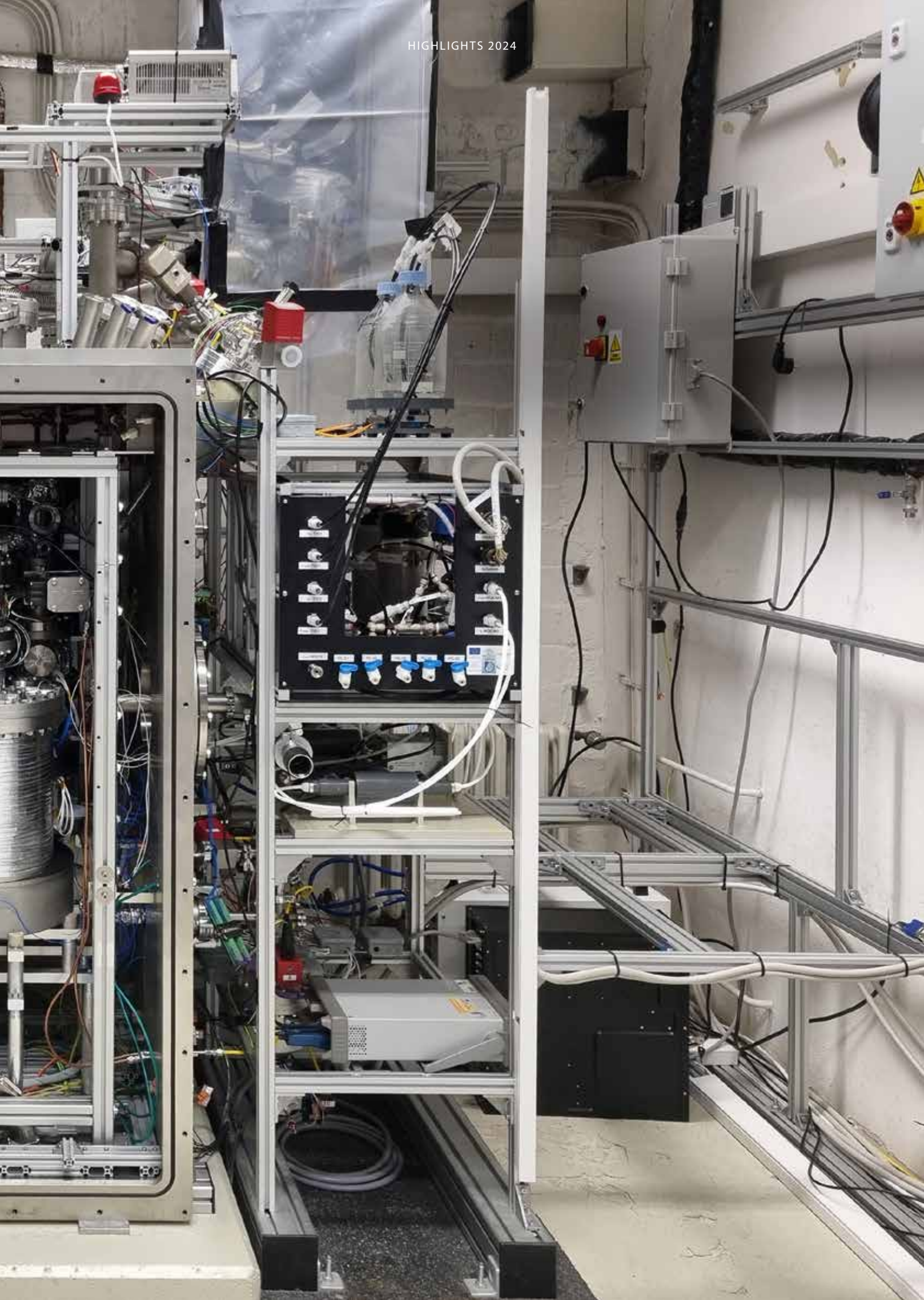
The LUWEX Experiment Team at TU Braunschweig in front of the vacuum chamber.

Mateo and Luca integrating LUWEX hardware.

FUNDED BY THE EUROPEAN UNION. VIEWS AND OPINIONS EXPRESSED ARE HOWEVER THOSE OF THE AUTHOR(S) ONLY AND DO NOT NECESSARILY REFLECT THOSE OF THE EUROPEAN UNION. NEITHER THE EUROPEAN UNION NOR THE GRANTING AUTHORITY CAN BE HELD RESPONSIBLE FOR THEM
LUWEX HAS BEEN FUNDED UNDER THE GRANT AGREEMENT NO. 101081937 – HORIZON 2022 - SPACE SCIENCE AND EXPLORATION TECHNOLOGIES.



The LUWEX experimental setup was assembled at the Faculty of Physics in Braunschweig. The water-capturing subsystem lays within a special thermal vacuum chamber that reproduces the temperature and pressure conditions in the lunar surface.



Rita extracting root material from aeroponic lettuce roots.

HUMANS ON MARS

2024 marked the third year of the University of Bremen's Humans on Mars Initiative, with research on the Sustainable Bioproduction on Mars Project continuing in the Planetary Infrastructures Laboratory. Jess Bunchek continued her doctoral work with colleagues at ZARM and the University of Bremen's Center for Environmental Research and Sustainable Technology (UFT). This year marked a milestone for the project, where processed substrate was successfully used as a nutrient solution to grow duckweed (Lemna minor L.). The substrate was extracted from cyanobacteria growing with Martian regolith simulant in a photobioreactor at Mars-like environmental conditions.
Other milestones included testing a collapsible aeroponic tray prototype with red romaine lettuce, designed and built with help from student alumnus Daniel Reppert López, as well as preliminary water stress simulation testing with help from student Rita Wolf. The project will continue into 2025 with funding from DLR, where testing will focus on novel plant health monitoring and irrigation methods.

Jess presenting at the European Low Gravity Research Association (ELGRA) symposium in Liverpool, UK.

Jess discussing her project with Anke Kaysser-Pyzalla, the Chair of the DLR Executive Board, at the Space Tech Expo in Bremen.

Inside view of a grow tray with aeroponic lettuce roots.

LAM-GTD project team during the CE study at Bremen's CEF in March 2024.

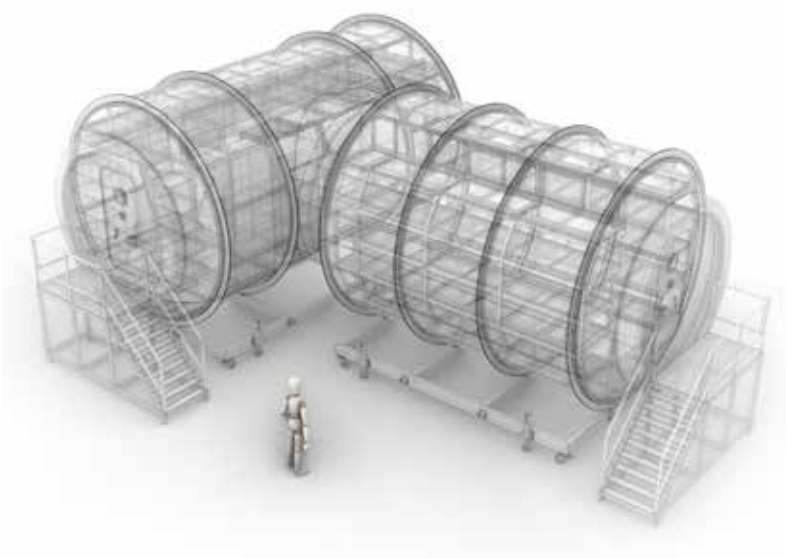
EDEN NEXT GEN.

DESIGNING THE LAM: GROWING IDEAS, CROSSING OCEANS

One of the main highlights in 2024 was the joint DLR/CSA design study, taking place at DLR's Concurrent Engineering Facility (CEF) in Bremen from March 7th to March 15th. During the study, more than 20 participants from Germany and Canada worked on aspects like the concept of operations, mass and power budgets, a preliminary set of requirements, and a first draft of the Ground Test Demonstrator's (GTD) layout. As part of this process, Controlled Environment Agriculture (CEA) subsystems like the Atmosphere Management System (AMS) were completely redesigned, yielding more space for other subsystems and, most importantly, for more crops.

The new total growth area of 23.5 m2, divided into a total of 48 trays, depicts a major improvement as it increases the biomass and oxygen output in a potential lunar exploration mission scenario.

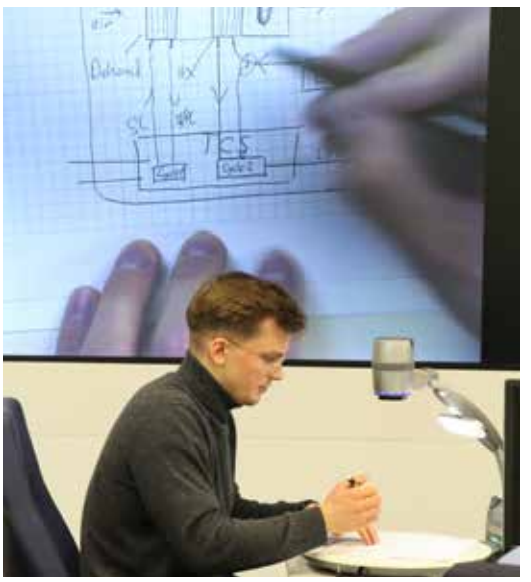
Throughout the year, substantial efforts were dedicated to the maturation of the subsystems and payloads. Technical Interchange Meetings (TIM) were held every quarter to synchronize the team's work on topics like the volume budget or requirements and specifications. Furthermore, a new mission logo was designed and renders were generated to visualize the project progress.



Conceptual rendering of LAM GTD's structure and platform.

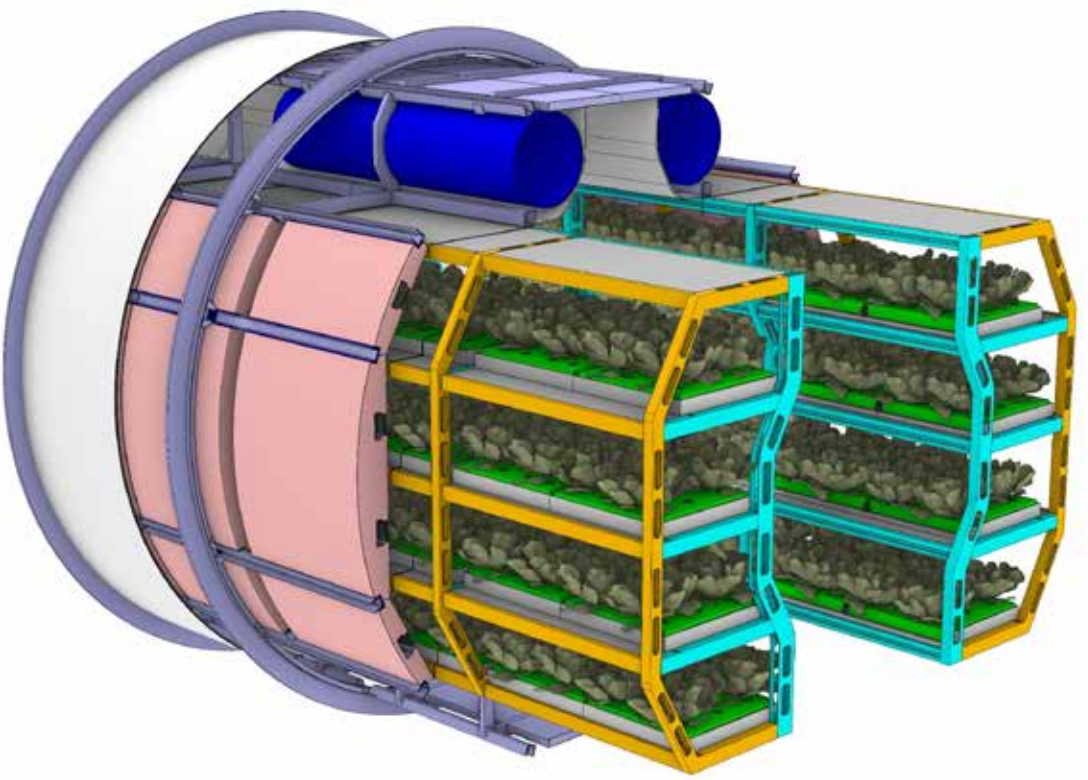
Guests & team leads from different space agencies. From left to right: Marta del Bianco (ASI), Ray Wheeler (NASA), Aubrie O'Rourke (NASA KSC), Conrad Zeidler (CSA/DLR), Jared Stoochnoff (CSA), Daniel Schubert (DLR).

The LAM-GTD project team engaging in technical discussions.



Jonathan Raecke drawing first schematic for the AMS.

The LAM-GTD project team during a domain round.

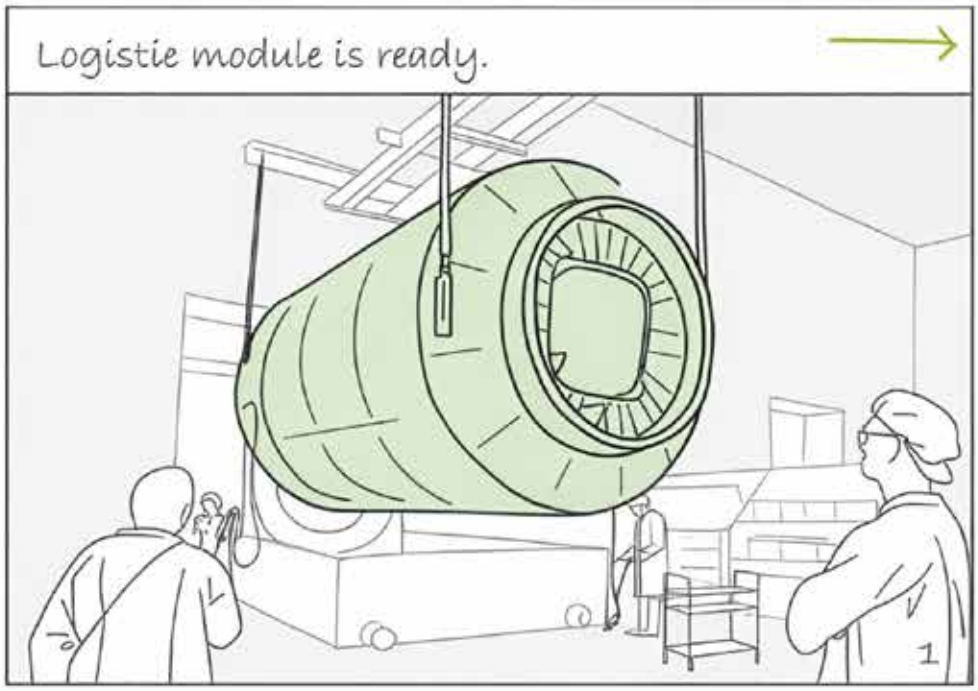


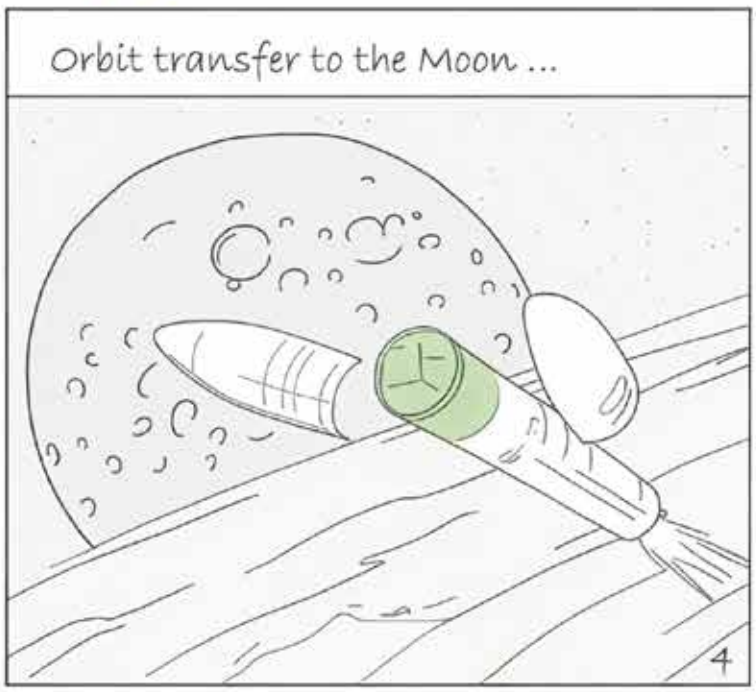
This is a rendering of the Ground Agriculture Module from 2025.

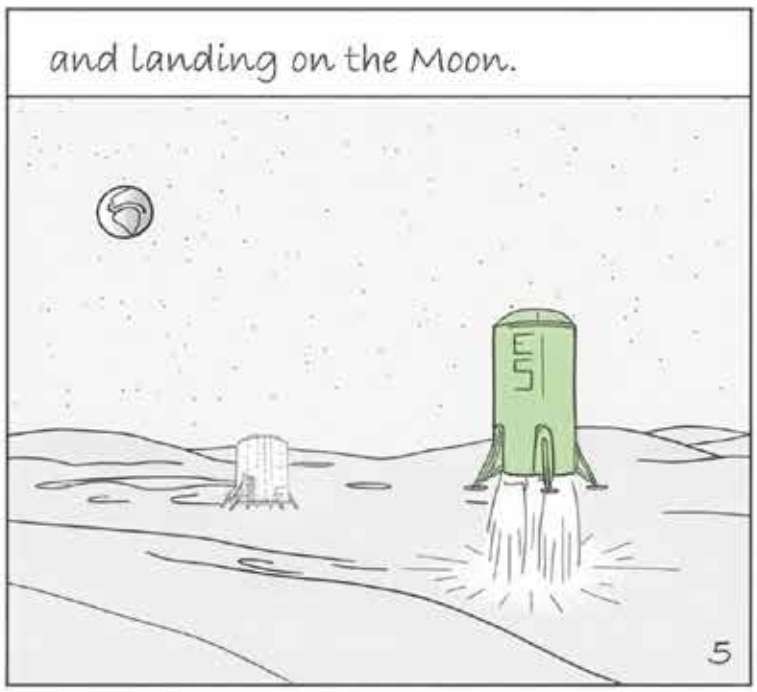
DLR

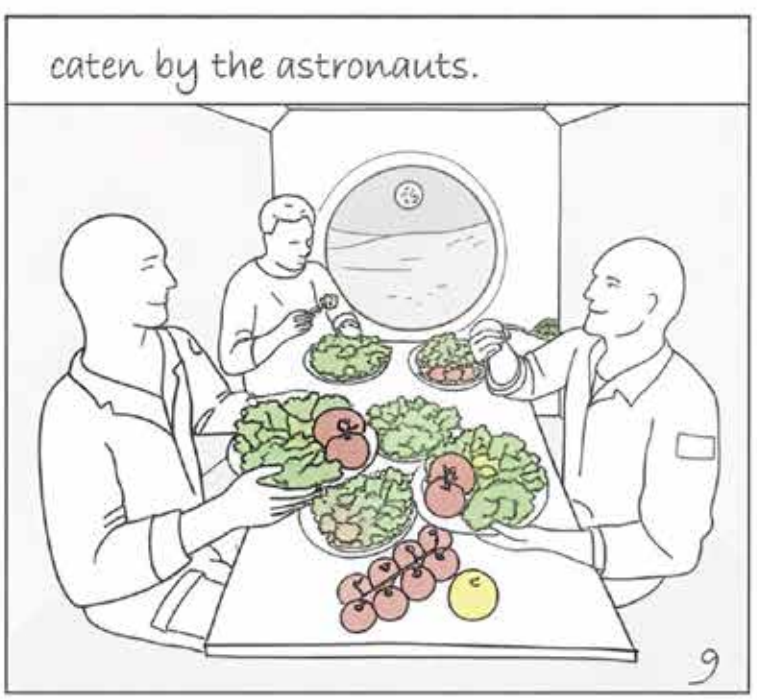
L2L

Logistic to Life Support Approach

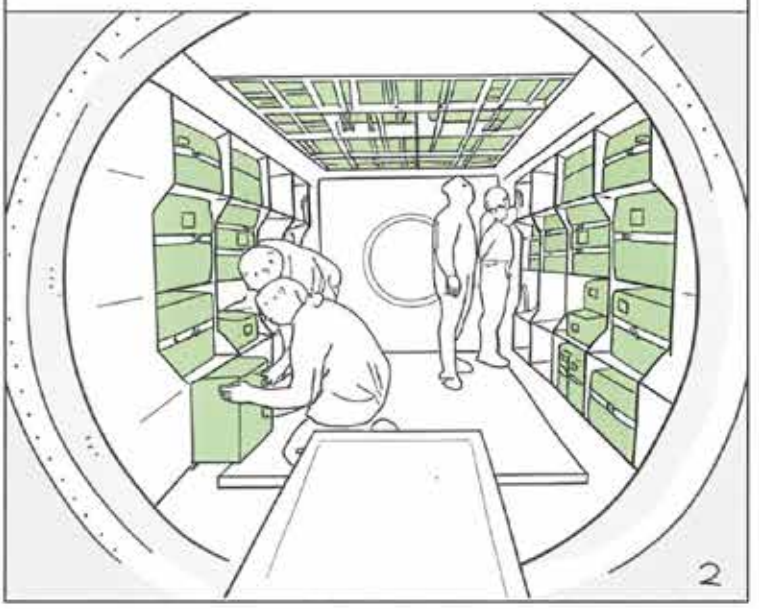




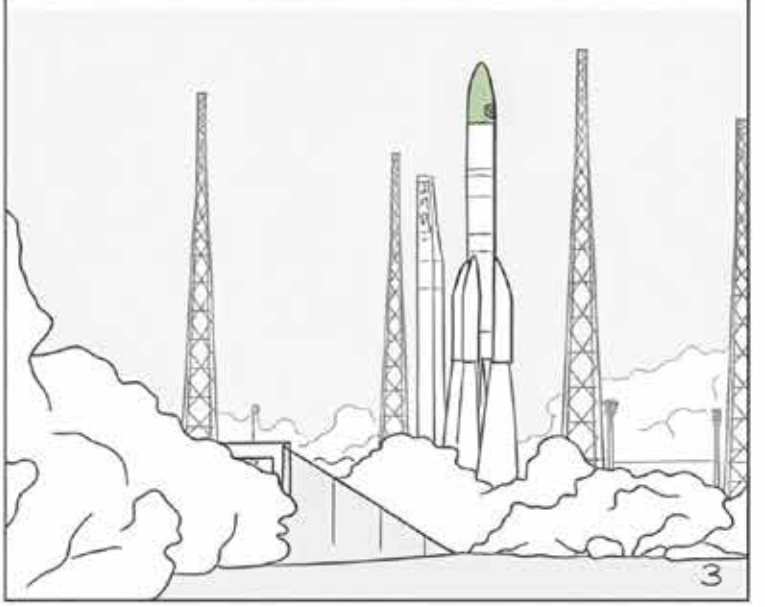




Integration of Cargo Transfer Bags.



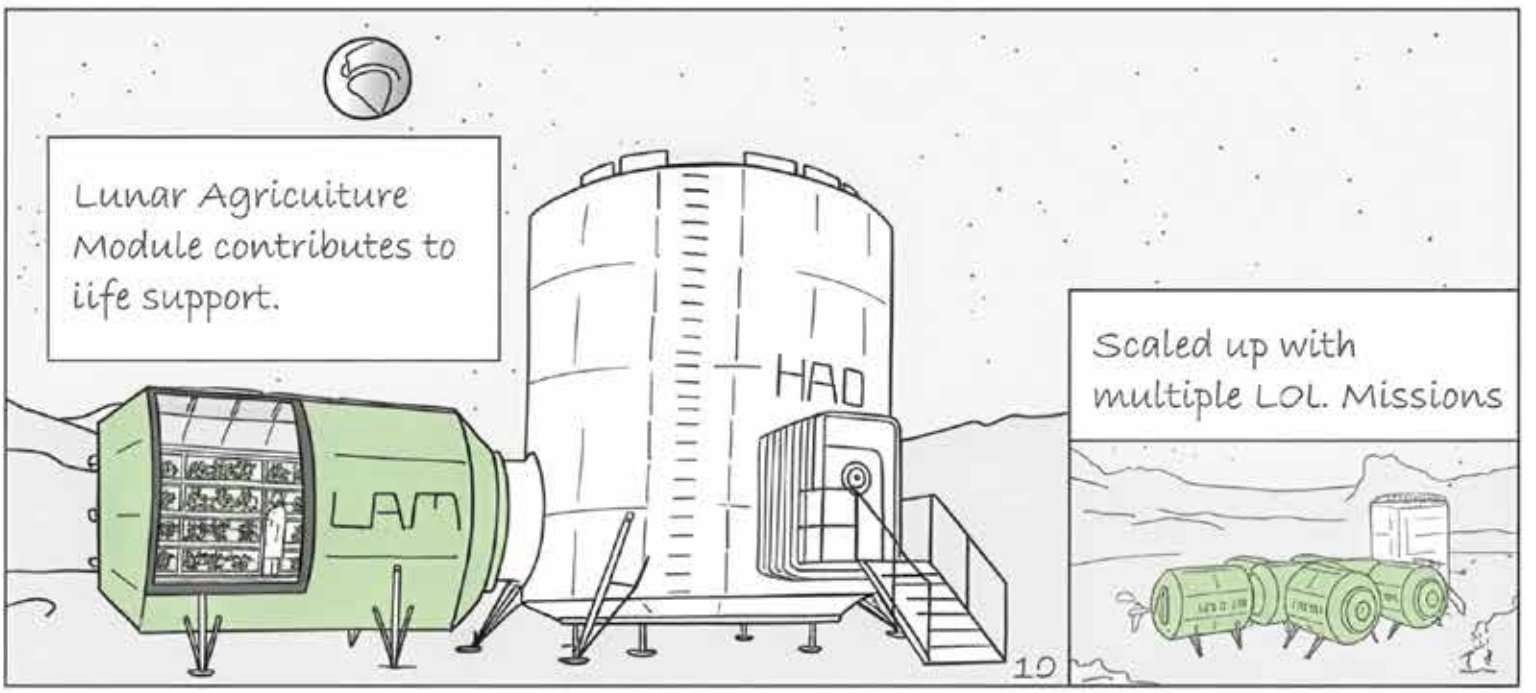
Lunar resuppiy mission is launched.



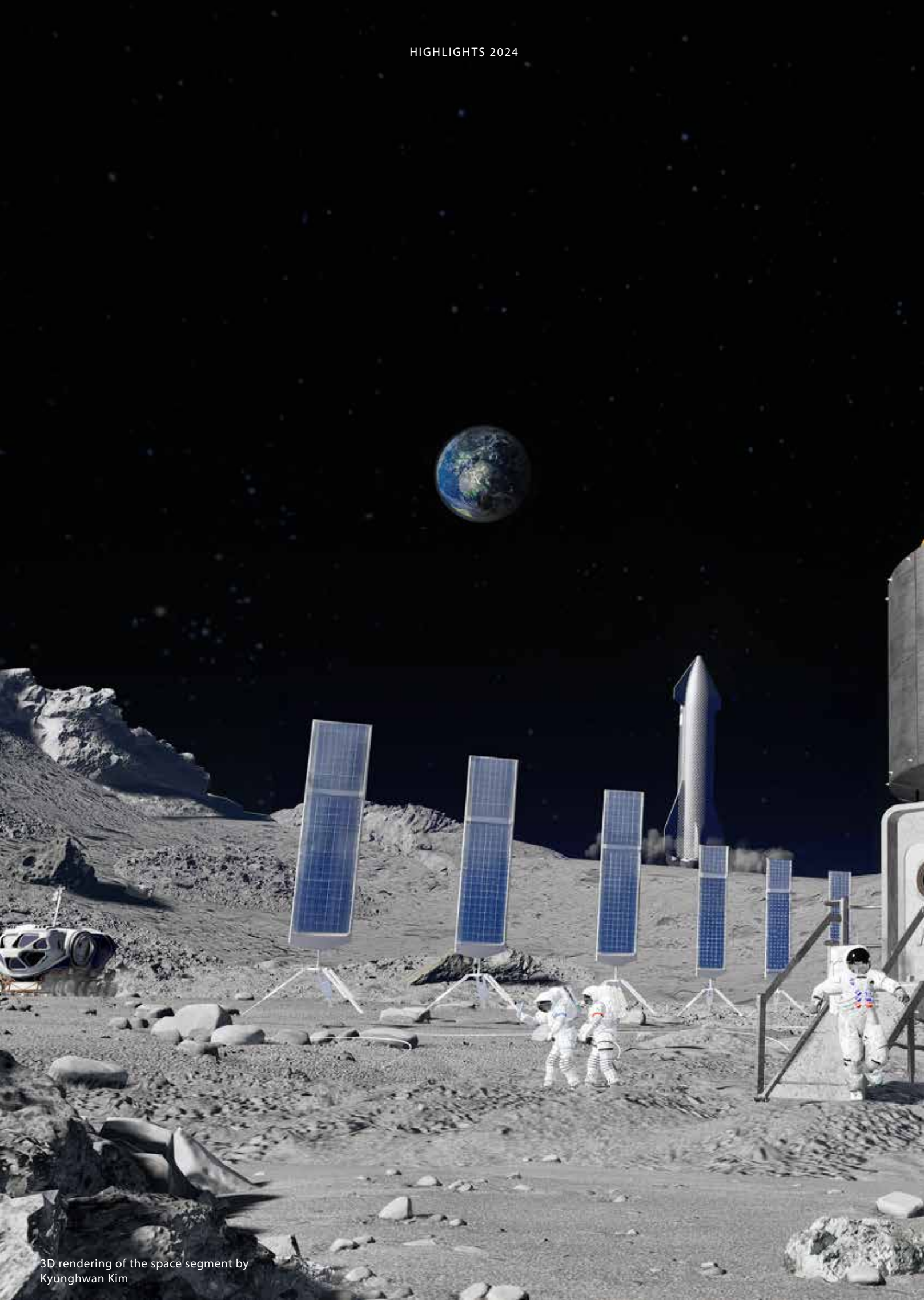
Astronauts offload cargo.

Setup of cultivation systems.

Lunar Agricuiture Module contributes to iife support.



Scaled up with multiple LOL. Missions



3D rendering of the space segment by Kyunghwan Kim


LAM-GTD
LUNAR AGRICULTURE MODULE
GROUND TEST DEMONSTRATOR
LUNAR HABITAT MODULE 01
LUNAR AGRICULTURE MODULE 01

Initial grow test with arugula in newly assembled plant rack.

BIOLOOPS

A SCALED EXPERIMENTAL HYDROPONIC SYSTEM FOR CONTROLLED PLANT GROWTH

For the EDEN group 2024 marked the beginning of the BioLoops project. Under the project lead of the Institute of Aerospace Medicine (DLR-ME) in Cologne, the EDEN team developed a multipurpose experimental cultivation setup, designed to explore the dynamics of hydroponic plant growth under controlled environmental conditions and pretreated urine as the main nutrient source for the plants.
The cultivation system features nine hydroponic gutters, each equipped with a recirculating water system (Nutrient Film Technique), where plants are nourished using a precisely monitored and controlled urine-based nutrient solution. The system's manifold further enhances experimental control, allowing independent regulation of volumetric flow to each gutter. Above the gutters, advanced LED lighting systems allow precise control over both light intensity, and spectral composition, enabling researchers to simulate and investigate various growth environments. BioLoops offers a versatile platform for advancing hydroponic agriculture research, with the potential to uncover new insights into plant growth with different recycled urine-based nutrient solutions. After a final test grow-out, the experimentalplatform will be delivered to DLR-ME in early 2025.

CAD model of the BioLoops production rack.

Luka is testing the nutrient solution flow in the plant production channel.

Adjustable nutrient solution flow distribution ensuring equal delivery to each channel.

LED top light bars above plant production channels.

Dr. Conrad Zeidler ladies & gentlemen!

Dr. Conrad Zeidler with his father Prof. Dr. Johannes Schöning and Rita Wolf on the left and Dr. Daniel Schubert, Dr. Lucie Poulet, Carolin Stellmacher and Prof.Dr. Rainer Malaka at his right after completing his PhD defence.

Conrad holding his PhD defence.

Dr. Conrad Zeidler's PhD graduation ceremony.

An augmented reality view of the inside of the HoloLens, showing a task list and information about the plants.

CONRAD'S PHD

„AUGMENTED REALITY IN A PLANETARY GREENHOUSE FOR CREW TIME OPTIMIZATION"

On June 24th, Conrad Zeidler defended his dissertation and received the degree of Doctor of Engineering (Dr.- Ing.) from the Faculty of Mathematics and Computer Science at the University of Bremen. The topic of his dissertation was "Augmented Reality in a Planetary Greenhouse for Crew Time Optimization". The dissertation was supervised by Prof. Dr. Johannes Schöning with Prof. Dr. Daniel Schubert as secondary reviewer. After the defense, Conrad received his doctoral hat, which was designed and manufactured by the students of the Planetary infrastructure group.

In his thesis, Conrad investigated how workload and crew time could be optimized for the operations of planetary surface greenhouses. Here, the importance of augmented reality for workflow optimization has increased in recent years in multiple application areas. Overall, the values and research on crew time, workload, and utilization of augmented reality applications presented in his thesis have significant implications for the design and operations of future planetary surface greenhouses, and the planning of related space missions. Further, these results can equally improve the reliability and efficiency of operations in today's terrestrial food production systems, such as commercial greenhouses and vertical farms.

Olivia is using augmented reality to evaluate crop care procedures, for future crew time optimization.

FURTHER HIGHLIGHTS

MORE HAPPENED DURING THE YEAR – FIND OUT WHAT:

VISIT OF SENATOR KATHRIN MOOSDORF

On July 31, 2024, Kathrin Moosdorf, Senator for Environment, Climate and Science, visited the German Aerospace Centre (DLR) in Bremen. During a guided tour with explanations of exhibits and insights into the laboratories, the institute's director, Prof. Andreas Rittweger, presented the senator with the research topics of the DLR-Institute of Space Systems.
The institute showcased models of current spacecraft, such as reusable rockets and satellites, and introduced the senator to space exploration missions. She was also given an in-depth look at the EDEN-laboratory, where Mrs. Moosdorf personally harvested cucumbers and tomatoes.

Maret Stolte, Deputy Head of the Northern Sites; Uwe Knodt, Administrative Director of the DLR Institute of Space Systems; Kathrin Moosdorf, Senator for Environment, Climate and Science; Prof. Andreas Rittweger, Director of the DLR Institute of Space Systems.

John Sims, Chuyan Chen, Trent Smith and Tor Blomqvist during the Deep Space Food Symposium.

NASA DEEP SPACE FOOD SYMPOSIUM

In July, team member Tor Blomquist flew to Ohio for the NASA Deep Space Food Symposium where academia, industry and national space agencies gathered to talk about the development of food systems for deep space. At this event, Tor moderated a panel discussion covering the roadmap for food for long term space exploration and what we need to achieve our goals. The panel also covered topics such as international and interdisciplinary collaboration, public private partnerships, and accessibility for terrestrial industry.

EXCELLENCE CLUSTER

Paul Zabel is one of 25 principal investigators who submitted the "Martian Mindset – A Scarcity-Driven Engineering Paradigm" proposal for an Excellence Cluster at the University Bremen to the Deutsche Forschungsgemeinschaft (DFG). The goal of the proposal is to investigate a full-scale production chain on Mars from beneficiating regolith over resource extraction and resource processing all the way to the manufacturing of spare parts and components utilizing local resources. The proposal made it into the full-proposal-stage and was defended in front of a review panel in November 2024 in Bonn. The results of the proposal evaluation will be announced around May 2025. If successful the Excellence Cluster would begin in January 2026 and would go on for seven years.

Cover image of the ESA-funded project Aeolis on Mars ISRU.

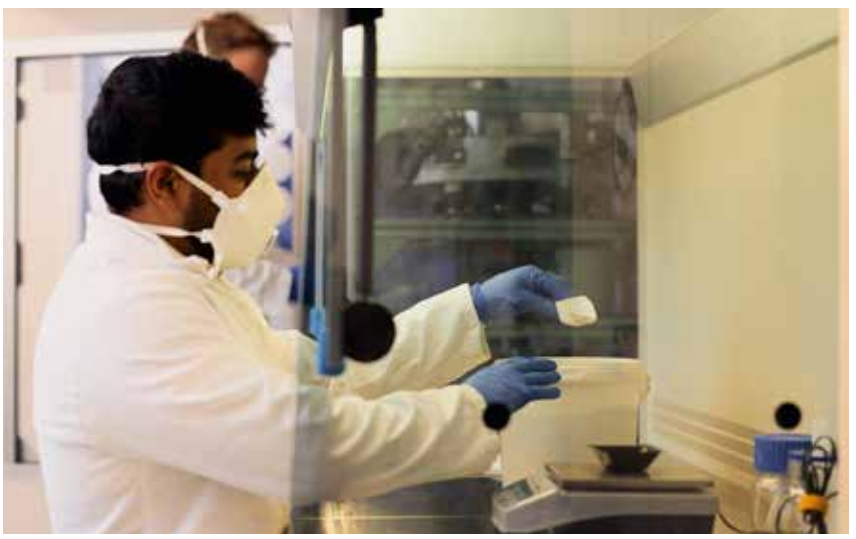
View of MEPA's redesigned SCM plant cultivation platform.

MARKET ANALYSIS FOR MEPA

After the official project ended in 2023, the MEPA topic continued to draw significant attention from visitors and stakeholders. MEPA is a fast-deployable plant cultivation system, specifically designed for harsh environments. Possible deployment areas are deserts or within refugee camps. With the support of the DLR technology transfer department, the EDEN group started an overall market analysis, and feasibility study in order to investigate the potential of the concept.

REGOLITH BENEFICIATION

The lunar regolith beneficiation testbed underwent a comprehensive experimental campaign in 2023. The testbed was developed to understand the dependencies of the system beneficiation performance on the various process parameters. Currently, a new testbed is under development that will use the same working principle as the laboratory setup but be more compact with a payload-style architecture to further increase the research fidelity. The regolith simulants also underwent an extensive characterization process focusing on all the mineral phases present within the simulants. The new setup is also aimed at demonstrating the feasibility of the system in the smaller scale to increase the overall extraction efficiency.



Kunal Kulkarni is working on a beneficiation experiment.

KEY FIGURES - 2024

JOURNALS

Kulkarni, K., Franke, M., Jundullah Hanafi, M.I., Gesing, T.M., Zabel, P. (2024): „Optimizing lunar regolith beneficiation for ilmenite enrichment. Frontiers in Space Technologies", 4. Frontiers Media S.A.. doi: 10.3389/frspt.2023.1328341. ISSN 2673-5075.

Steinert, S., Zabel, P., Quantius, D. (2024): „Location dependent flight cost differences from the lunar surface to an orbital fuel depot and its influence on ISRU location selection". Frontiers in Space Technologies. Frontiers Media S.A.

Freer, R., Pesch, V., Zabel, P. (2024): „Experimental study to characterize water contaminated by lunar dust", Frontiers in Space Technologies. Frontiers Media S.A.

Bunchek, J.M., Hummerick, M.E., Spencer, L.E., Romeyn, M.W., Young, M., Morrow, R.C., Mitchell, C.A., Douglas, G.L., Wheeler, R.M., Massa, G.D. (2024): „Pick-and-eat space crop production flight testing on the International Space Station". Journal of Plant Interactions, 19(1)

Wheeler, R.M., Spencer, L.E., Bhuiyan, R.H., Mickens, M.A., Bunchek, J.M., van Santen, E., Massa, G.D., Romeyn, M.W. (2024): „Effects of elevated and super-elevated carbon dioxide on salad crops for space", Journal of Plant Interactions, 19(1)

Gross, Ch., Al-Samir, M., Bishop, J. L., Poulet, F., Postberg, F., Schubert, D. (2024): Prospecting in-situ resources for future crewed missions to Mars. Acta Astronautica, 223, Seiten 15-24. Elsevier. doi: 10.1016/j.actaastro.2024.07.003. ISSN 0094-5765.

Ikeya, Kosuke and Guerrero-Gonzalez, Francisco J. and Kiewiet, L. and Cardin, M.A., Cilliers, J., Starr, S., Hadler, K. (2024): „Hybrid lunar ISRU plant: a comparative analysis with carbothermal reduction and water extraction." Acta Astronautica. Elsevier. doi: 10.48550/arXiv.2408.04936 Add to Citavi project by DOI. ISSN 0094-5765.

PEER-REVIEWED CONFERENCE PROCEEDINGS

Fonseca Prince, A., Lutze, J.P., Maier, M., Friedl, W., Leidner, D., Philpot, C., Vrakking, V., Ksenik, E., Schubert, D. (2024): „EDEN Versatile End-effector (EVE): An Autonomous Robotic System to Support Food Production on the Moon.", 03-09. March 2024, IEEE Aerospace Conference, AERO 2024. IEEE. 2024 IEEE Aerospace Conference, Big Sky, Montana, USA. doi: 10.1109/AERO58975.2024.10521422. ISBN 979-835030462-6. ISSN 1095-323X.

Vrakking, V., Philpot, C., Schubert, D., Aksteiner, N., Strowik, C., Ksenik, E., Sasaki, K., Toth, N., Franke, M., Bunchek, J.M., Bornemann, G., Holbeck, I., Fonseca Prince, A., Rewicki, F. (2024) System Design of the EDEN LUNA Greenhouse: Upgrading EDEN ISS for future Moon mission simulations. 53rd International Conference on Environmental Systems, 21-25 July 2024, Louisville, Kentucky, USA.

Blomqvist, T.A. (2024) Creating an independent food system in space. Fraunhofer Future Days, 31 January - 01 Febuary, Freising.

Blomqvist, T.A. (2024): „HABSIM – Unique R&D Infrastructure for closed-loop food production in space and on Earth", American Chemical Society, ACS Spring 2024, PAPER ID: 4040785 DIVISION: Division of Agricultural and Food Chemistry SESSION: Sensory Beyond Earth: The Relevance of Flavor Chemistry in Space Exploration.

Blomqvist, T.A., (2024) „Regulatory food safety challenges when transitioning to a space food production system.", International Conference on Alternative Proteins for Food and Feed,03-05 December 2024, Berlin.

NORMAL CONFERENCE PROCEEDINGS/ PRESENTATION

Blomqvist, T.A. (2024): „VESTA - Creating an independent food system in space", Future Days Fraunhofer Institute for Process Engineering and Packaging IVV and the Industrial Association for Food Technology and Packaging IVLV e.V.

Blomqvist, T.A. (2024): „Creating an intependent food system in space", Güntners Impact Summit, 04 -07. September 2024, Budapest, Hungary.

Franke, M. (2024): „Developing plant cultivation technologies for space at DLR - from Antarctica to the Moon", 28th European Low Gravity Research Association symposium (03-06 September 2024), Liverpool (UK)

Zabel, P., Kiewiet, L. (2024): „Experimental Demonstration of Lunar Water Extraction and Purification", Space Resources Week 2024, 25-27 March 2024, Luxembourg.

Kim, K.H, Schubert, D., Vrakking, V., Bunchek, J.M (2024): „EDEN 2.0 greenhouse design study for Neumayer Station III in Antarctica.", 45th COSPAR Scientific Assembly, 13- 21 July 2024, Busan, South Korea.

Kim, K.H., Blomqvist, T.A., Schubert, D. (2024): „Concept study of a centralized test facility for advancing space food system.", 45th COSPAR Scientific Assembly, 13-21 July 2024, Busan, South Korea.

Bunchek, J.M., Hummerick, M.E., Franco, C., Massa, G.D. (2024): „Nutrition of Antarctic-grown crops to supplement the crew diet, with applications for spaceflight" (NASA Human Research Program Investigators' Workshop, 13-16 January 2024, Galveston, TX, USA;)

Bunchek, J.M., Ramalho, T.P., Pillot, G., Kerzenmacher, S., Schubert, D., Vereux, C. (2024). "Sustainable Bioproduction on Mars Subproject 3: Hardware & Integrated Testing" (University of Bremen - Humans on Mars Workshop, 19 June 2024)

Bunchek, J.M., Hummerick, M.E., Franco, C., Williams, D.C., Spencer, L.E., Ramalho, T.P., Vrakking, V., Schubert, D., Massa, G.D., Fritsche, R.F., Wheeler, R.M. (2024): "Nutrition of Antarctic-grown crops to supplement the crew diet, with applications for spaceflight" (COSPAR, Busan, South Korea; 13-21 July 2024)

Bunchek, J.M., Hummerick, M.E., Spencer, L.E., Romeyn, M.W., Young, M., Morrow, R.C., Mitchell, C.A., Douglas, G.L., Wheeler, R.M., Massa, G.D. (2024): „Pick-and-eat space crop production flight testing on the International Space Station" (13-21 July 2024, COSPAR, Busan, South Korea)

Bunchek, J.M., Zabel, P., Romeyn, M.W., Vrakking, V., Wolf, R., Schubert, D. (2024): „Successes, Challenges, and Delicious Surprises: Lessons Learned from Plants Grown in EDEN ISS in Antarctica." (03-06 September 2024, ELGRA, Liverpool, UK)

Vrakking, V., Philpot, C., Schubert, D., Dorn, M., Bunchek, J.M. (2024) „EDEN Research Group: Overview of Bio-regenerative Life Support System research at the German Aerospace Center", 13-21 July 2024, COSPAR 2024, Busan, South Korea.

Philpot, C., Vrakking, V., Schubert, D., Aksteiner, N., Strowik, C., Ksenik, E., Sasaki, K., Toth, N., Franke, M.F., Bunchek, J.M., Bornemann, G., Holbeck, I.M., Fonseca Prince, A., Rewicki, F. (2024): „DLR-ESA LUNA Greenhouse: from Antarctica to Europe's Lunar Analog Facility. International Space Station Research & Development Conference", 30 July - 01 August 2024, Boston USA.

Kulkarni, K.M., Zabel, P., Rejon Lopez, M., Kiewiet, L. (2024) „ISRU Advancements: Regolith beneficiation and propellant production overview.", 04-07 June 2024, in: Space Resources Roundtable. Colorado School of Mines. Space Resources Roundtable XXV Meeting, Golden, Colorado, United States.

Maiwald, V., Neufeld, C., Franke, M.F., Schubert, D. (2024): „Lunar Agricultural Module Ground Test Demonstrator – an international approach for realizing plant-based bio-regenerative life-support", 14-18 October 2024, 75th International Astronautical Congress, Milan, Italy.

Kim, K.H., Blomqvist, T.A., Schubert D., Maiwald V. (2024): „Centralized Testing Facility Uniting Food Systems for Space Exploration", 14-18 October 2024, 75th International Astronautical Congress, Milan.

Fonseca Prince, A., Friedl, W., Leidner, D., Vrakking, V., Philpot, C., Schubert, D. (2024): „Preliminary study on how an autonomous robotic system can impact the crew time during plant cultivation on the lunar surface", 14-18 October 2024, 75th International Astronautical Congress, Milan, Italy.

INVITED TALKS

Zabel, P., : „Synergetic Material Utilization - ISRU activities at the DLR Institute of Space Systems - Regolith Beneficiation and Water Extraction", Invited talk in course LSS and ISRU at University Stuttgart, 28 May 2024.

Rejon Lopez, M. (2024) : „La cara oculta de la luna: una nueva perspectiva de nuestro satélite natural.", Encuentro Nacional de Estudiantes de Física 2024, Granada, Spain, 03-06 September 2024.

Kiewiet, L., : „An overview of the LUWEX project. Oberseminar Geo und Astorphysik", Braunschweig, Germany, 30 April 2024.

Bunchek, J.M., : „EDEN ISS: plant production facility ground testing.", National Academies of Science, Engineering, & Medicine - Committee on Biological and Physical Sciences in Space (Washington, D.C., USA; presented remotely; 20 March 2024)

Bunchek, J.M., : „The Human Element of Growing Plants in the Unlikeliest of Places." (Science Goes PUBlic, Bremen, 14 March 2024)

Kim, K.H., Schubert, D., : „Utilizing the Terrestrial Antarctic base of the German Space Center (DLR) for manned exploration of the Moon.", 66th Korean Aerospace Medicine Association Spring Conference, Seoul, South Korea, 24 May 2024.

Dorn, M., : „MEPA: Growing fresh food for humanitarian crisis response.", DLR Colloquium „Technologies for Humanitarian Relief", online, 06 March 2024.

Schubert, D., : „Analogue Testing of Plant Cultivation Technologies for Space", Space Architecture Workshop, Titan - Disruptive Innovation Center, Milano, Italy, online, 16 July 2024.

Philpot, C., „Bio-regenerative Life Support System for higher plants EDEN LUNA", Lecture BLSS, Technical University Munich, November 2024.

Rejon Lopez, M., „Lunar Water Extraction and Purification — Space Resources at DLR Bremen." Aqualunar Innovator Bootcamp, Montreal, Canada (Online), November 2024.

Schubert, D., „Antarktis-Projekt EDEN / LUNA „Plant cultivation for future habitats on the Moon and Mars", event: Astroherbst, house of science, Braunschweig, November 2024.

DIPLOM-/ MSC.-/ BSC.-THESIS

Wache, H. : „Thermal Conductivity Measurements of Dry and Icy Lunar Regolith Simulants", Master Thesis, Technische Universität Braunschweig, 2024.

Heitkamp, M. : „Lunar Water Extraction: Design, Optimization, and Development for future Space Exploration. Master's", Master Thesis, Twente University, 2024

Kalis, C. : „Design of a Water Capturing System for Thermal Extraction of Water on the Moon In the context of In-Situ Resource Utilisation (ISRU)." Master Thesis, 2024.

Koch, Y. : „Analysis and Evaluation of an In-Situ Resource Utilization Based Structure of a Lunar Greenhouse", Master Thesis, University of Bremen, 2024.

Zachau, J. : „Development of an Environmental Control and Life Support System (ECLSS) for the Next Generation European Human-Rated Spacecraft", Master Thesis, University of Bremen, 2024.

Kopecny, B.A. : „Entwicklung einer modularen Steuerung für eine mobile Pflanzenanbau- und Nährstoffversorgungseinheit.", Bachelor Thesis, University of Bremen, 2024.

Behnke, L.A., „Investigation of optimal Light Environments for crops in EDEN LUNA", Bachelor Thesis, Technical University of Berlin, 05 November 2024.

POSTER

Heitkamp, M., Kiewiet, L. (2024): „Accurate modelling of ISRU technologies by CFD and DEM.", 25-27 March 2024, Space Resources Week, Luxembourg.

Wache, H., Kiewiet, L. (2024): „Investigation on the Thermal Properties of an Lunar Icy Regolith Simulant.", 25-27 March 2024, Space Resources Week 2024, Luxembourg.

Bunchek, J.M., Schubert, D., Ramalho, T.P., Pillot, G., Kerzenmacher, S., Vereux, C. (2024): „Nutrient Composition & In-Situ Irrigation Capabilities for Space Crop Production Systems", 20 February 2024, University of Bremen - Humans on Mars Workshop.

SPECIAL

Zabel, P., „Member of the ICES International Committee and co-chair of session 204 ‚Bioregenerative Life Support."

Zabel, P., „Topic Editor for Frontiers in Space Technologies - Special Issue on Technologies for Prospecting, Extraction, and Utilization of Space Resources."

Vrakking, V., Reviewer for a paper submission to the 53rd International Conference on Environmental Systems, 2024.

Buncheck, J.M., Reviewer for a paper submission to the 53rd International Conference on Environmental Systems, 2024.

Blomqvist, T.A, Deep Space Food Challenge, Expert judge phase 3.

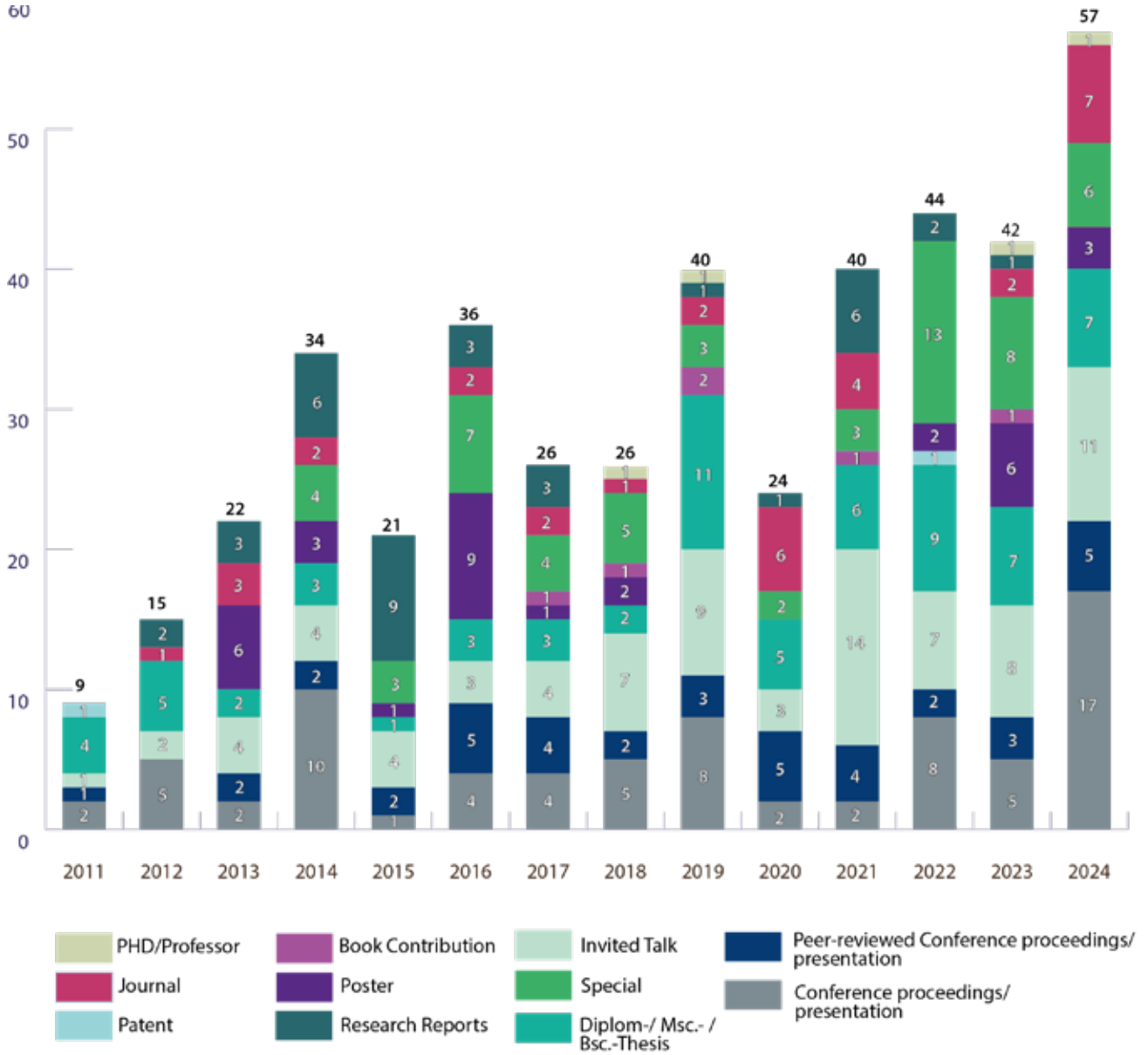
Blomqvist, T.A., Moderator for industry panel discussion, Deep Space Food Symposium Columbus, Ohio, USA.

PHD/ PROFESSORSHIP

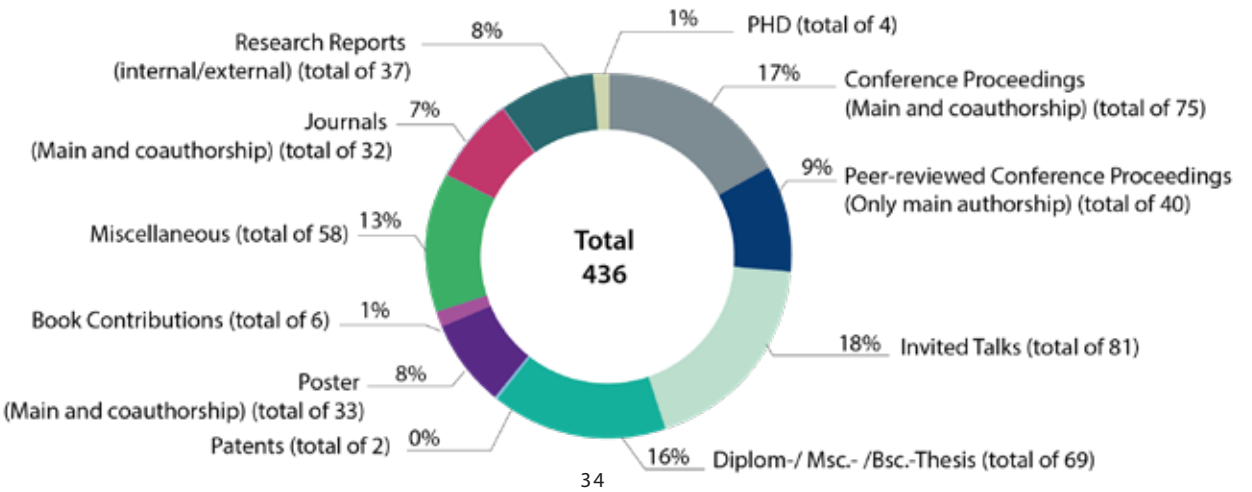
Zeidler, C. : „Augmented Reality in a Planetary Greenhouse for Crew Time Optimization", Dissertation, University of Bremen. doi: 10.26092/elib/3105, 2024.

SUMMARY KEY FIGURES

PUBLICATIONS & KEY FIGURES 2011-2024

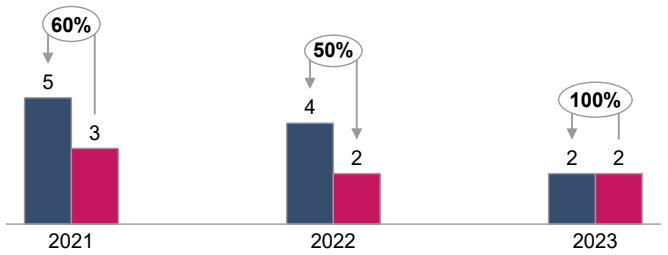


TOTAL PUBLICATIONS & KEY FIGURES 2011–2024

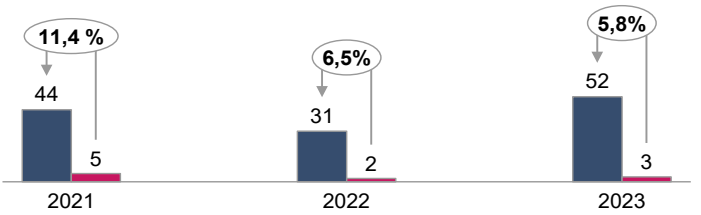


CONTRIBUTIONS TO THE INSTITUTE'S KEY PERFORMANCE INDICATORS (KPI)*:

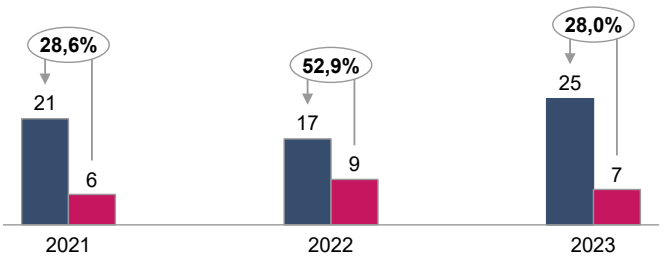
Guest Scientists:



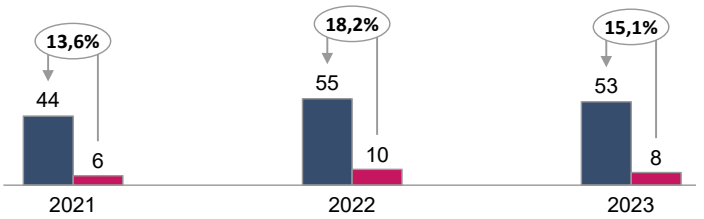
Conference Proceedings:



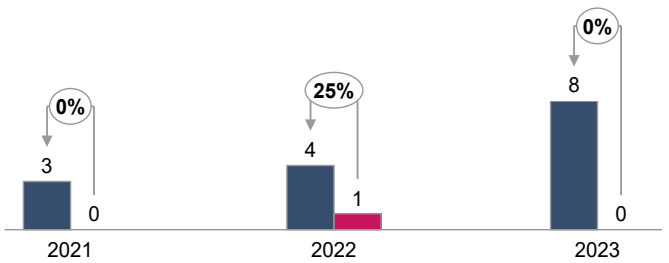
Diplom-/Msc.-/Bsc.-Thesis:



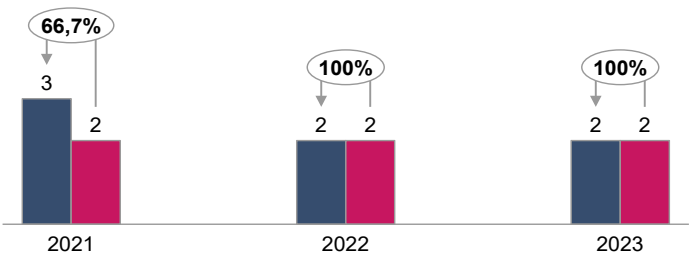
Peer-reviewed Publication



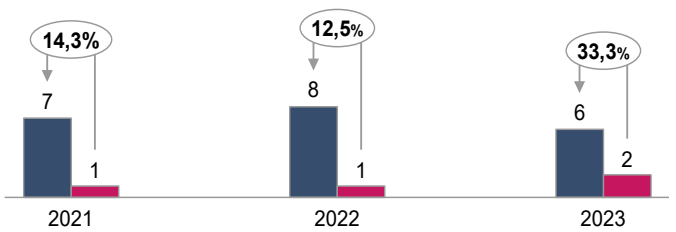
Approved Patents:



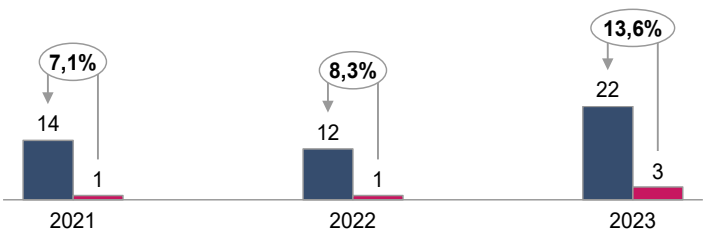
DLR Dissertation Contracts:



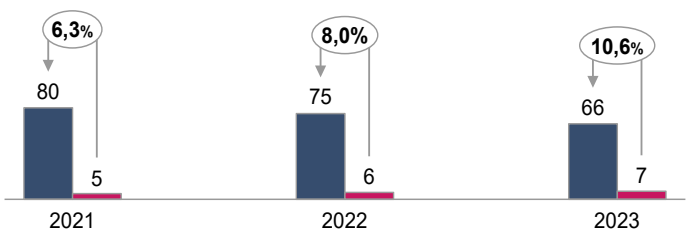
Scholarships:

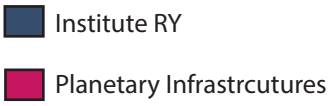


International Employees:



Kat-1 Employees (Grundfinanziert):





*Values are based on the Institutsentwicklungsplan 2024 (IEP) of the Institute of Space Systems in comparison to selected and partly combined key figures of the Planetary Infrastructures Cluster. Shown are the grops´s contribution towards the KPIs of last three years. (2021-2023)

PLANETARY INFRASTRUCTURES STUDENTS

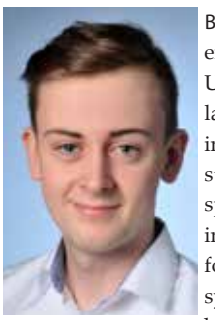
Without the assistance and help of highly-motivated students, the success of the EDEN Initiative would not have been possible! Therefore the entire EDEN team would like to say thank you. See below what the student's tasks were and what they are doing now:

JULES GÖTTE studies communication, media, and cultural studies at the University of Bremen. He joined the EDEN team in June 2024, focusing on PR and outreach. With a background in videography and media, he enhances the team's presence on digital and analog platforms, working on social media, video, and print while reaching out to individuals, companies, collaborators, and other DLR departments.

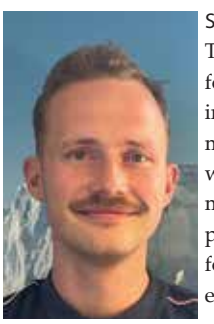
LUKA THIES is a master's student in Space Engineering at University Bremen. After discovering his passion about bio-regenerative life support systems during his bachelors programm at FH Aachen, he joined the EDEN team as a student assistant in May 2024. Supporting the team in the EDEN laboratory, the MEPA project and the EDEN LUNA project, he is assisting with engineering tasks and in the workshop. Additionally he is also helping maintaining the 3D-printing farm.

SVENJA FÄLKER absolved her dual studies at Hochschule Bremen in 2021 and is currently studying aerospace engineering at master level at TU Dresden. She joined the Group in July 2023 and uses her previous work experience to support the LUWEX project. There she supports the development, design and testing of a stirring mechanism for lunar regolith and the programming of a LabView software for the data handling and control system of the extraction and liquefaction subsystem.

PRÈVE CHOBERT-PASSOT studied architecture in Paris and pursue with a Master of Space Science (MSc) from the International Space University (ISU) in Strasbourg. At DLR, she is writing a thesis on the design of a workstation for EDEN Next Gen. She also supported the EDEN LUNA Team, primarily by creating renders.



BJARNE KOPECNY, a student of production engineering specializing in aerospace at the University of Bremen, joined the DLR team in late 2022 through a university project. Initially involved in developing a business plan for a startup focusing on a terrestrial application of space greenhouse systems, Bjarne transitioned into a more hands-on role as a student assistant, focusing on the development of a new control system for the MEPA system as part of his bachelor's thesis.



SIERT HAMERS, a Space Engineering student at TU Delft, who has joined the EDEN LUNA team for an internship. He is focused on developing innovative methods to enhance plant health monitoring systems. A significant part of his work involves upgrading camera technology to more effectively detect signs of plant stress. In addition, Siert is responsible for maintaining the 3D print farm, ensuring all equipment operates smoothly.

ALWYN SAJU is an M.Sc. Space Engineering student at the University of Bremen, focusing on "Human space exploration and habitation." In 2022, he began a DLR project on terrestrial applications of space greenhouse technology. Since 2024, he has been a student assistant with the Planetary Infrastructures team, contributing to projects MEPA, EDEN Next-Gen and BIOLOOPS.

SASKIA WESER is a master's student in Horticulture at the University of Applied Sciences Dresden (HTW Dresden), with a strong interest in extraterrestrial plant production and advanced cultivation systems. As part of her master's thesis, she is developing a comprehensive plant protection concept for space greenhouses to ensure the supply of fresh food. She is also responsible for all horticultural tasks in the laboratory and conducts experiments to cultivate less-explored plant species and varieties in the aeroponic system at the EDEN Lab.

MART HEITKAMP eagerly returned, following his previous internship at DLR, this time to defend his mechanical engineering thesis at the University of Twente. His role involves conducting research into experimental optimization. The focus is on modelling various phenomena, such as heat transfer and ice deposition, to thoroughly investigate and optimize the LUWEX experiment scheduled for 2024.

OLIVIA MENDELSON is a Bioresource Engineering Master's student from McGill University, Montreal, Canada. She previously did an 8-month internship at the Canadian Space Agency. During her time at DLR, Olivia participated in the EDEN NEXT GEN/GTD Concurrent Engineering (CE) Study in March 2024 as the Biomass domain. Her focus is on running plant growth

HENNING WACHE Henning Wache was a master's thesis student from the Technical University of Braunschweig (Germany). Henning worked on developing the icy regolith simulant for the LUWEX project and measuring the thermal conductivity of this material, in order to help understand the results of water extraction experiments.

DAVID HAEFNER is an aerospace engineer (B.Sc. from TU Dresden) and master's student in space engineering at the University of Bremen. He works as a student researcher at the German Aerospace Center (DLR) in Bremen, contributing to the LUWEX project, which focuses on lunar water extraction and beneficiation technologies for mining lunar regolith to produce in-situ oxygen, and metal feedstocks.

AYLIN BAYLAN studies communication and media at the University of Bremen. She joined the EDEN team in July 2021 as a student assistant and supports the team in tasks regarding PR and outreach. Her daily work routine includes different organizational processes such as contacting interested persons, collaboration partners, and PR teams from other DLR departments. Her area of responsibility also includes supporting several social media accounts and overseeing the yearly report.

LEA BEHNKE studies aerospace engineering at TU Berlin. She joined the EDEN group in March 2024 for an internship and her Bachelor's thesis. During her thesis, she developed and programmed individual light recipes for plants used in the EDEN LUNA project. The goal is to heighten the output by the greenhouse.

SANDRA ROBSON studies aerospace engineering at KTH Royal Institute of Technology and is part of the EDEN team for her master thesis. Her thesis is focused on a comparative analysis between current Life Support Systems on the ISS and bioregenerative approaches, such as the EDEN Greenhouse. The study evaluates their potential for future long-duration space missions, including advancements in life support and food production strategies to support sustained human presence in space.

LASSE BRUUN holds a M.Sc. in Aerospace Engineering from Technical University of Delft. After finishing his thesis research at Massachusetts Institute of Technology, he joined the EDEN LUNA team to update the drainage system of the trays and test the light system that is used in EDEN LUNA.

TABEA ERLINGHAGEN is studying Applied Plant Biology - Horticulture (B.Sc.) at the Osnabrück University of Applied Sciences. She is an intern at DLR and writing her bachelor thesis at the institute. In her work she is involved in plant cultivation in the EDEN Lab and helps with experiments on plant cultivation in hydroponic systems. The purpose of the research there is to ensure the supply of fresh food as part of projects such as MEPA, EDEN LUNA and EDEN Next Gen.

IMPRESSIONS 2024

SEE WHAT ELSE HAPPENED DURING THE YEAR....

Dr. Daniel Schubert, our team leader during the "Homecoming" of our EDEN ISS/LUNA Greenhouse.

The DLR Startup Factory TOUR begins.

Senator Katrin Moosdorf is visiting the DLR Institute of Space Systems; here, taking a closer look at our EDEN ISS model.

Anna Christmann, former federal Government Coordinator for German Aerospace holding a speech at the opening of the ESA-DLR LUNA analogue facility.

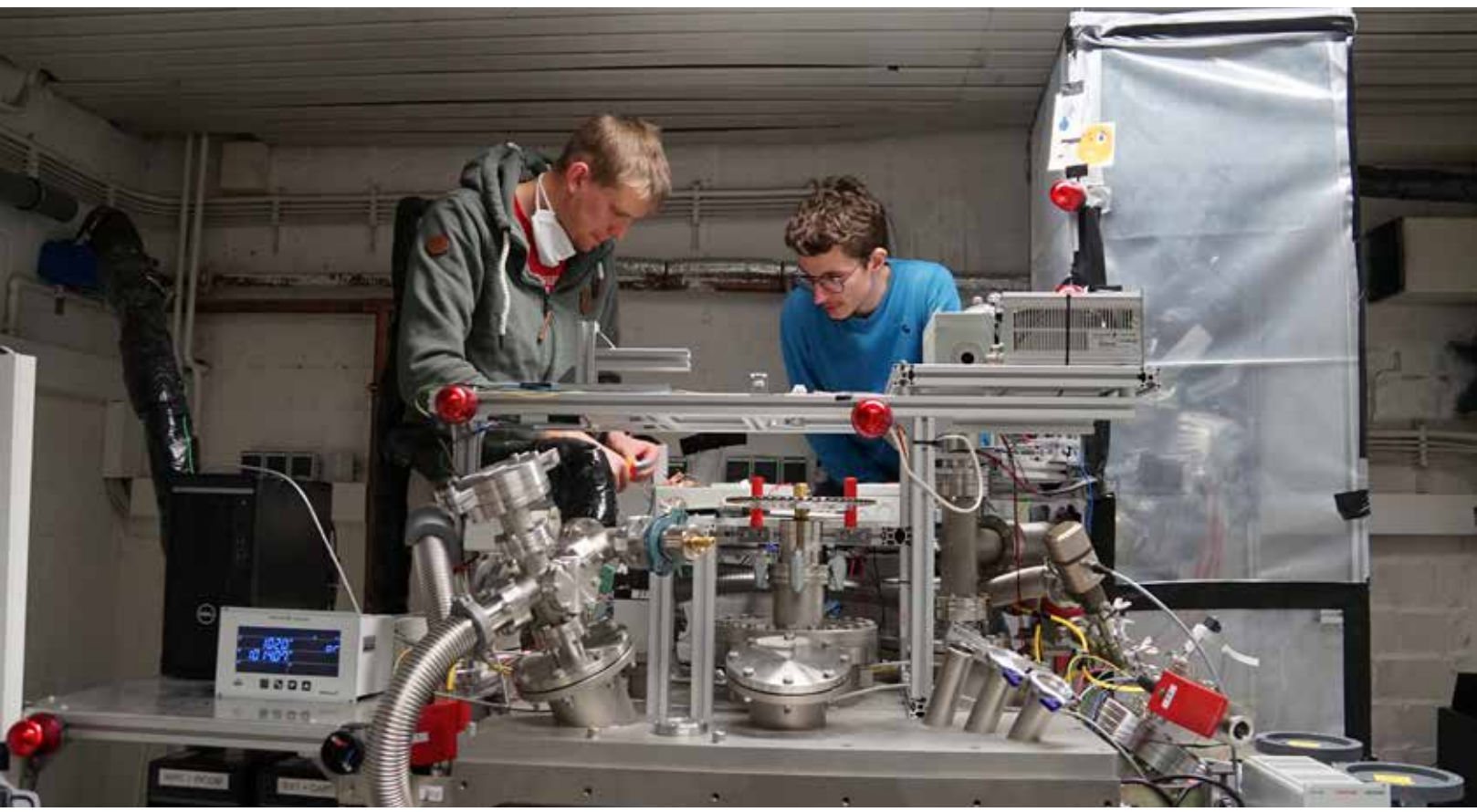
Alexander Gerst, ESA astronaut, Mona Neubau, Minister of Economic Affairs, Industry, Climated Protection and energy of North Rhine Westphalia and ESA Director Joseph Aschbacher at the opening of the ESA-DLR LUNA analogue facility.

Astronauts in action: Petra Mittler, Tom Uhlig, Jurgen Schlutz and Andrea Cassini at the opening of the ESA-DLR LUNA analogue facility.

Lucie Poulet visiting the closed-loop test facility.

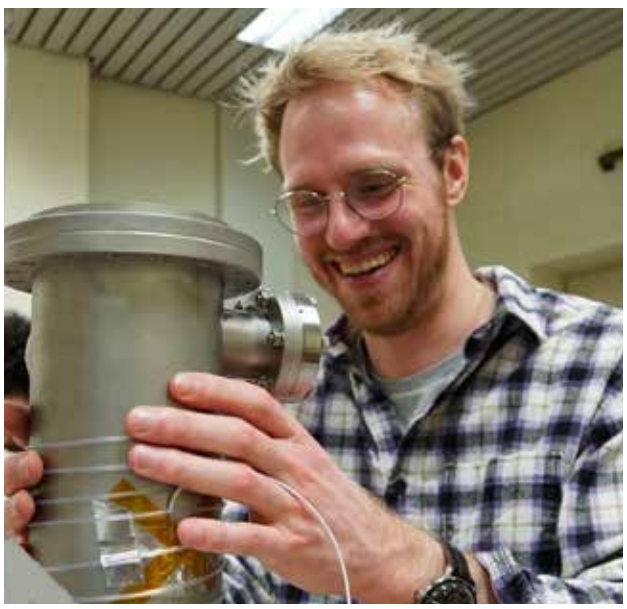
A close-up of a cucumber flower growing in a PI-laboratory.

The whole LUWEX team taking a well deserved pizza-break at work.

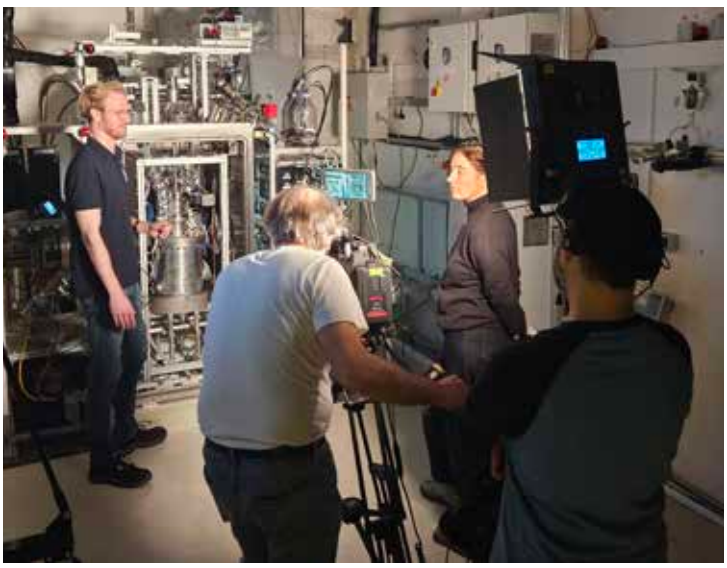


Luca Kiewiet and Dr. Paul Zabel preparing the icy regolith simulant.

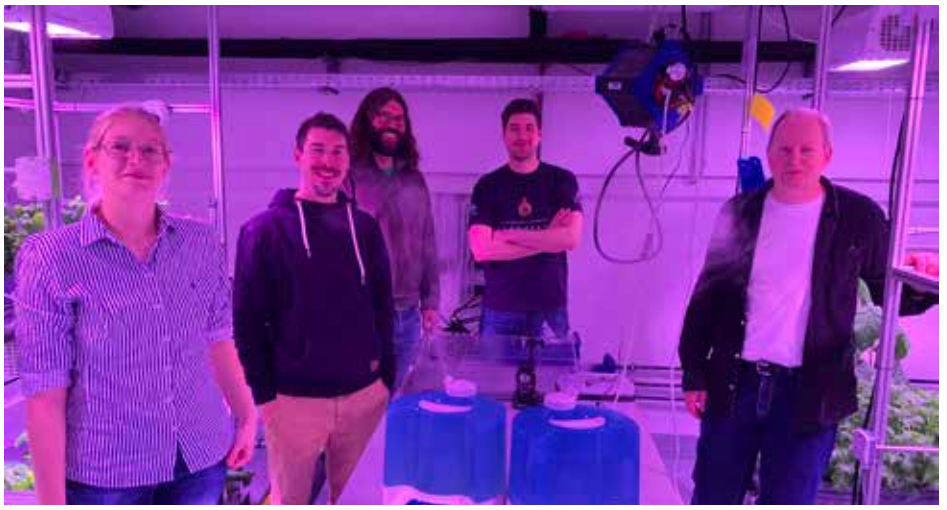
Cooling the regolith simulant before mixing in ice.



Luca seemingly happy while diving into his passion: space engineering.



A German film crew interviews and films Luca in the workshop for a LUWEX related tv-clip.

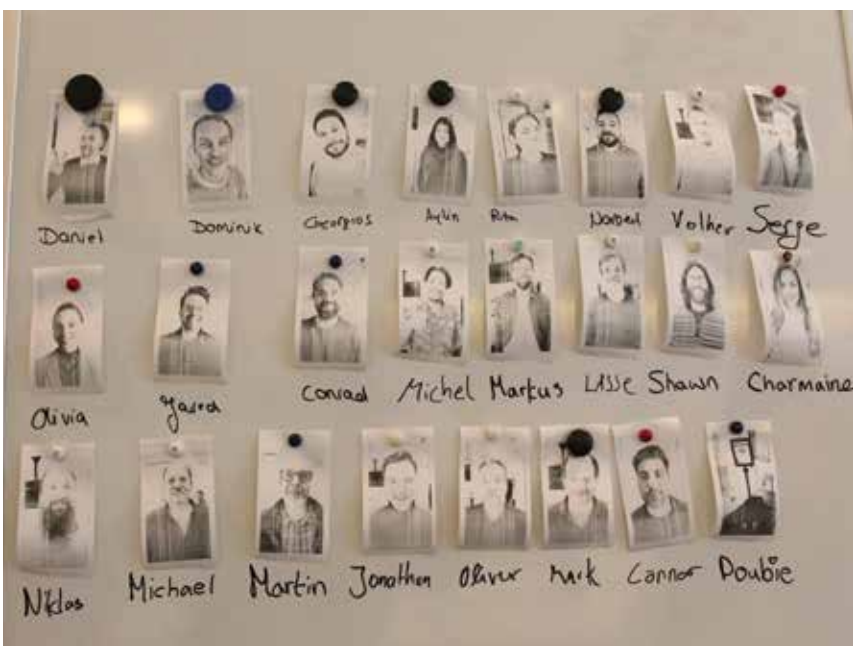


Laboratory visit during the CE-Study.

Mark Lefrud talking through the remote avatar robot to the NASA colleague Trent.

Dinner event after the sucessfull CE-Study day.

Volker and Niklas in fruitfull discussion about the CE-Study



Check in Board for the CE-Study participants.

EDEN LUNA Team celebrating first milestone during the AIV phase.

Markus and Paul, the grill masters at the team social event.

A little inside look at the beautiful green around our Planetary Infratstrucutres summer party.

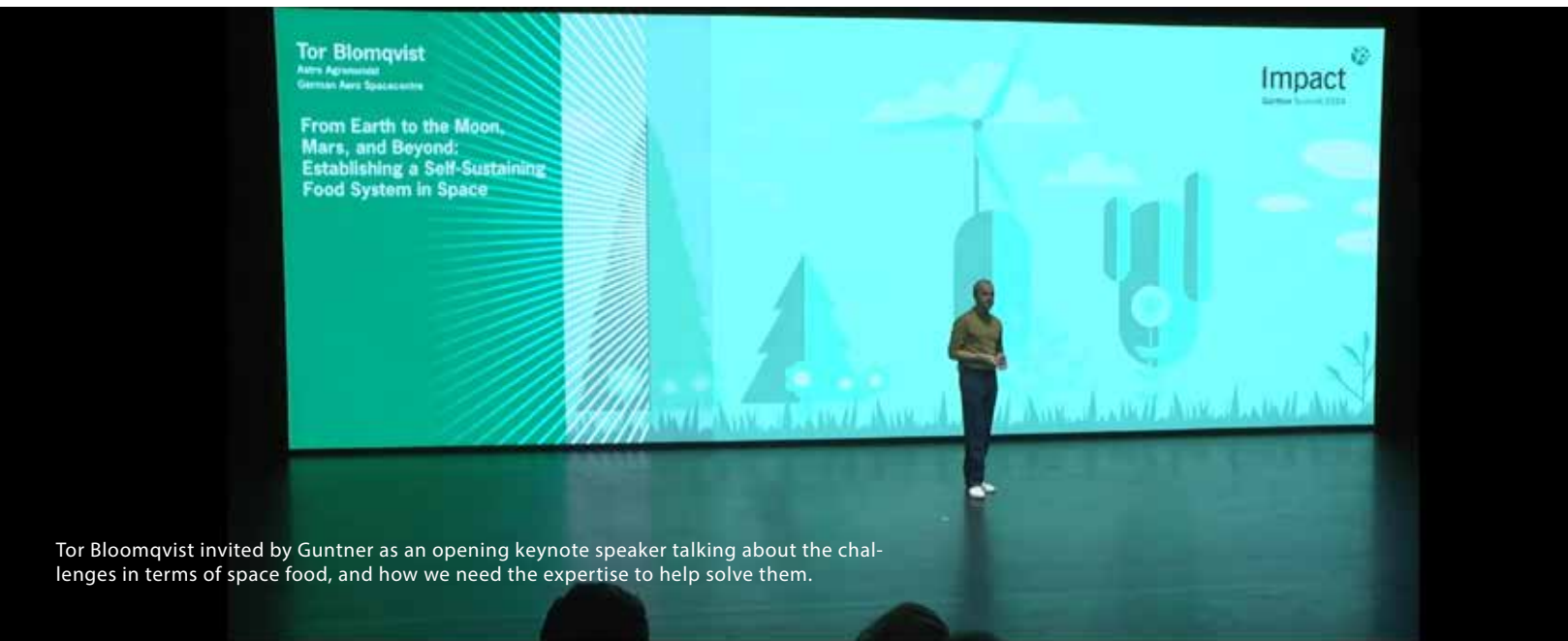
Kunal, a happy grillmaster.

The team at our Planetary Infrastructures summer party!

Tor is being interviewed on TV about terrestrial spinnoffs and applications for space tech.

Michel Fabien Franke is holding a presentation about the transformation of EDEN ISS into EDEN LUNA at the International Astronautical Congress (IAC) 2024 in Milan.

TV interview of Mateo Rejón López at Canal Sur Andalucía.



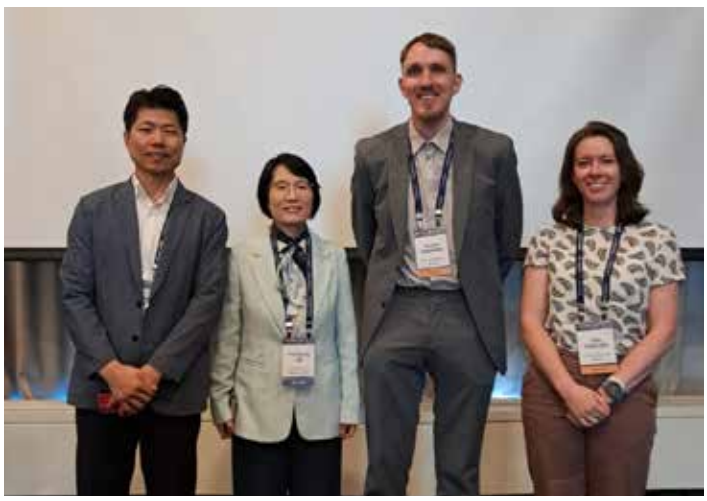
Tor Bloomqvist invited by Guntner as an opening keynote speaker talking about the challenges in terms of space food, and how we need the expertise to help solve them.

EDEN LUNA PM, Claudia Philpot, meets CSA partner and former EDEN ISS system engineer, Matthew Bamsey, at the ISS R&D conference in Boston, USA.

Claudia Philpot presenting EDEN's plant growth modules and its opportunities at ISS Research and Development Conference in Boston, USA.

Vincent Vrakking presenting at COSPAR 2024.

Kyunghwan Kim presenting EDEN LUNA at the 2024 COSPAR.



Kyunghwan Kim, Yoo Kyung Lee, Vincent Vrakking and Jess Bunchek at COSPAR 2024.

Michel and Markus conquering project management in Oberpfaffenhofen.

The team at our annual Christmas get-together.

Kyunghwan and Mart at the christmas party.

Jess and Saskia at our christmas party.

Livia, Luca and Mateo at our christmas party.

Mart and Luka enjoying food and drinks at our christmas party.

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Goettingen, Hamburg, Jena, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart,Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

YR-ED-2024 – issue1

Imprint

Issue1
Bremen, 24th of June 2025

Publisher:
German Aerospace Center
Deutsches Zentrum für Luft und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft
Institute of Space Systems
Department of System Analysis Space Segment (SARA)

Address:
Robert-Hooke-Str. 7
D-28359 Bremen
Phone +49 (0) 421 24420-1136
Fax: +49 (0) 421 24420-1150
e-mail daniel.schubert@dlr.de
http://www.dlr.de/irs/desktopdefault.aspx/tabid-11287/

DLR.de

Editors:
Prof. Dr. Daniel Schubert
Dr. Paul Zabel
Dr. Conrad Zeidler
Vincent Vrakking
Michel Franke
Kunal Kulkarni
Claudia Philpot
Jess Bunchek
Jennifer Götte
Luca Kiewiet
Jules Götte
Markus Dorn
Tor Blomqvist
Christian Schnorr

Design:
Annemarie Popp
annemarie.popp@web.de
Jules Götte
Jennifer Götte

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag