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HIGHLIGHTS 2019

YEARLY STATUS REPORT
EDEN INITIATIVE





Skidoo tour near the Neumayer Station III during the maintenance mission in 2019

EDEN – THE YEAR 2019

Almost exactly four years (March 2015 to May 2019) was the duration of the EDEN ISS project. Four years of intensive work, ups and downs - but all rewarded with the successful deployment of the research greenhouse in Antarctica. These four years pushed the EDEN group to a new level by establishing essential know-how, not only on a technical level also through the operational aspects of managing a multinational analogue mission with 15 partners from 8 countries. As the EDEN ISS container remains in Antarctica, the research and testing will continue. The year 2019 also marked an important year for the EDEN group by establishing its pathway to planetary system deployment. With the EDEN ISS NEXT design, the group established a first baseline design for future space greenhouse systems.

Transferring space-rated systems to terrestrial applications was always one of the main goals of the EDEN group. With the new MEPA system and the upcoming development project, the group will design a rapid deployable food production system for crisis scenarios. The official grand opening of the educational Botanika exhibition was an important milestone for the public engagement activities of the EDEN group. The exhibit will remain a permanent part of the visitor center of the Botanika, establishing a useful communication tool for the coming years. The EDEN team looks confidently to the future as its development pathway for creating bioregenerative life support systems continues. The operation of the Antarctic research platform EDEN ISS will generate useful knowledge on the operational challenges of these systems.

Dr. Daniel Schubert



Arrival of the DLR crew together with the AWI personnel at the Russian NOVO runway (Antarctica) in January 2019

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Harvest inside the EDEN ISS Future Exploration Greenhouse (FEG) in January 2019



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.

EDEN was established within the DLR internal project CROP (Combined Regenerative Organic-Food Production) – a joint research endeavor between the Institute of Aerospace Medicine (ME) and the Institute of Space Systems (RY).

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 Moon and Mars are still several years from coming to fruition, the time to develop these technologies needs to start today. Only this way, highly-reliable and resource-efficient BLSS will be ready for implementation into the mission architecture for humanity's journey to the Moon and Mars.

The EDEN Initiative is administered by the Department of System Analysis Space Segment (SARA) at DLR Bremen. The department operates the institute's Concurrent Engineering Facility (CEF) as well as the Space Habitation Plant Laboratory (EDEN Lab). Furthermore, the EDEN group receives support from the institute's Electronic Laboratory (E-Lab), and utilizes the institute's laboratory building (incl. integration hall) in order to foster the development of cutting-edge plant cultivation technologies.



DLR Institute of Space Systems, Bremen (Germany)



Making up hydroponic nutrient solution within the EDEN Lab analytical room

THE EDEN TEAM



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. In 2011, he initiated the EDEN group at the DLR Institute of Space Systems for technology investigations on Bio-regenerative Life Support Systems and since served as the team leader of this group. His research expertise is set on habitat interface analysis and plant accommodation and dynamic plant production planning.



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 since 2012, before joining the team in 2015. Within the EDEN group he investigates the potential use of lightweight inflatable materials and structures that can house Bio-regenerative Life Support Systems and greenhouse systems in particular.



MARKUS DORN is a horticulture expert and holds a M.Sc. in plant sciences (University of Natural Resources and Life Sciences, Vienna, Austria). He joined the team in 2017 as an external consultant and advises the team in horticultural questions. He has evaluated different plant candidates and also developed cultivation methods for fruit trees for use within planetary habitats. He is mainly responsible for the organization of the EDEN plant lab.



CONRAD ZEIDLER has been a member of the EDEN research team since January 2011. Within 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 environment parameters.



DR. PAUL ZABEL studied aerospace engineering at the Technical University of Dresden. He joined the EDEN team in 2012. Dr. Zabel is the deputy manager of the EDEN Lab and is working on acquiring funding and projects for EDEN. His research expertise is hybrid Life Support Systems containing greenhouse modules and physical/chemical LSS.



Conrad Zeidler filling the wastewater tanks before bringing them to the station



Preparation of the nutrient salts for the upcoming isolation phase



Clean-up of the Future Exploration Greenhouse (FEG observation camera)



The harvest was used for a dedicated salad bar during dinner inside the station



Inedible biomass after the harvest inside the EDEN ISS Future Exploration Greenhouse (FEG) in January 2019

EDEN ISS MAINTENANCE MISSION

THE MISSION GOES ON...

... as DLR officially took over the operational cost of the EDEN ISS research platform, ensuring operation and science for the future to come. From January to February, four EDEN members, along with two partners of the University of Florida, travelled back to the Antarctic research platform. The agenda for this trip was to make necessary repairs after its first year of operation. Additional samples were taken, the facility was cleaned, and several technical systems were improved (e.g. scaled-up stock solution unit). A highlight was the official visit of the HGF delegation, organized by the German Parliament. During the visit, Prof. Dr. Boetius (Head of AWI), Prof. Dr. Wiestler (Head of Helmholtz Gesellschaft), and several members of the delegation visited the EDEN ISS greenhouse system.

After the maintenance team left, the greenhouse was put into hibernation mode. This was done to allow the EDEN group to test procedures related to a remote, automated restart of the facility similar to an actual space scenario. In May 2019 the second operation phase was then initiated, with on-site operations being handled by the overwintering crew of the Neumayer Station III.



Implementing new 3d-printed plant holding adapters for the plant trays



Conrad Zeidler and Markus Dorn installing new sensors



2019 maintenance crew (from left to right): Dr. Daniel Schubert (DLR), Vincent Vrakking (DLR), Prof. Dr. Rob Ferl (University of Florida), Prof. Dr. Anna-Lisa Paul (University of Florida), Conrad Zeidler (DLR), and Markus Dorn (DLR)



2019 marked the 10 year anniversary of the Neumayer Station III. For this reason the AWI executive board, together with a dedicated group of the Helmholtz Association, as well as members of German government were visiting the station. During the visit, a tour through the EDEN ISS greenhouse was undertaken as well.
Source: Esther Horvath (AWI)





Final EDEN ISS project team during final presentation

EDEN ISS FINAL PRESENTATION

15 PARTNERS, 8 COUNTRIES, 4 YEARS, 1 ANTARCTIC GREENHOUSE

On the 22nd and 23rd of May 2019, the EDEN ISS consortium held the final presentation for the EDEN ISS project, thereby officially concluding the Horizon2020 project. The 15 project partners from 8 countries gathered for a last time at DLR's Institute of Space Systems in Bremen to present and discuss the results of the final project phase. Main topic was the first operations phase of the EDEN ISS Mobile Test Facility in the Antarctic.

Together with the European Commission's project supervisor (Vojko Bratina) and the project reviewers (Prof. Dr. Stefania De Pascale and Dr. Jack van Loon), additional aspects were discussed, such as future space applications, possible spin-offs, and opportunities to leverage the unique Antarctic greenhouse infrastructure for future research- and collaboration initiatives. The meeting concluded with the presentation of the official EDEN ISS documentary and the European children's design competition.



Dr. Paul Zabel presenting the final results of the one year analogue mission in Antarctica



The project team had to score the children's design contest (see also page 30 & 31)



Lunch time during final presentation



Using DLR's servicing bar for lunch time



Useful discussions during one of the coffee breaks

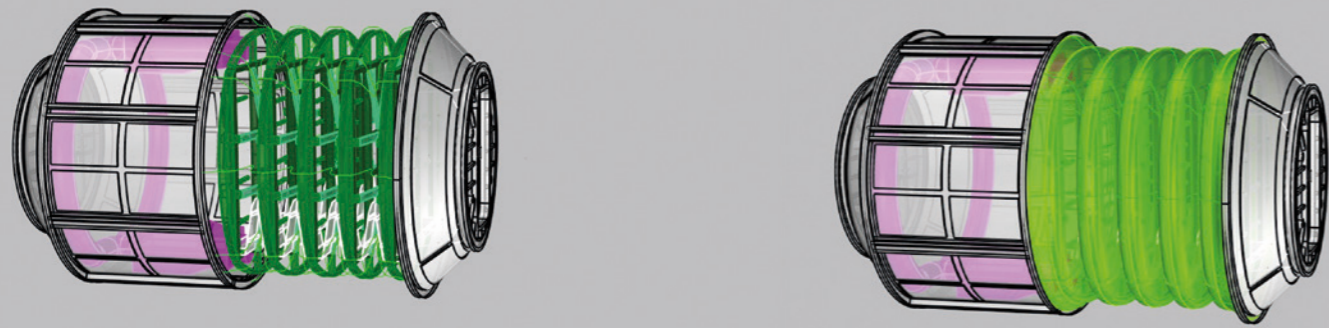


Main presentation room; All partners were presenting their final results



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636501



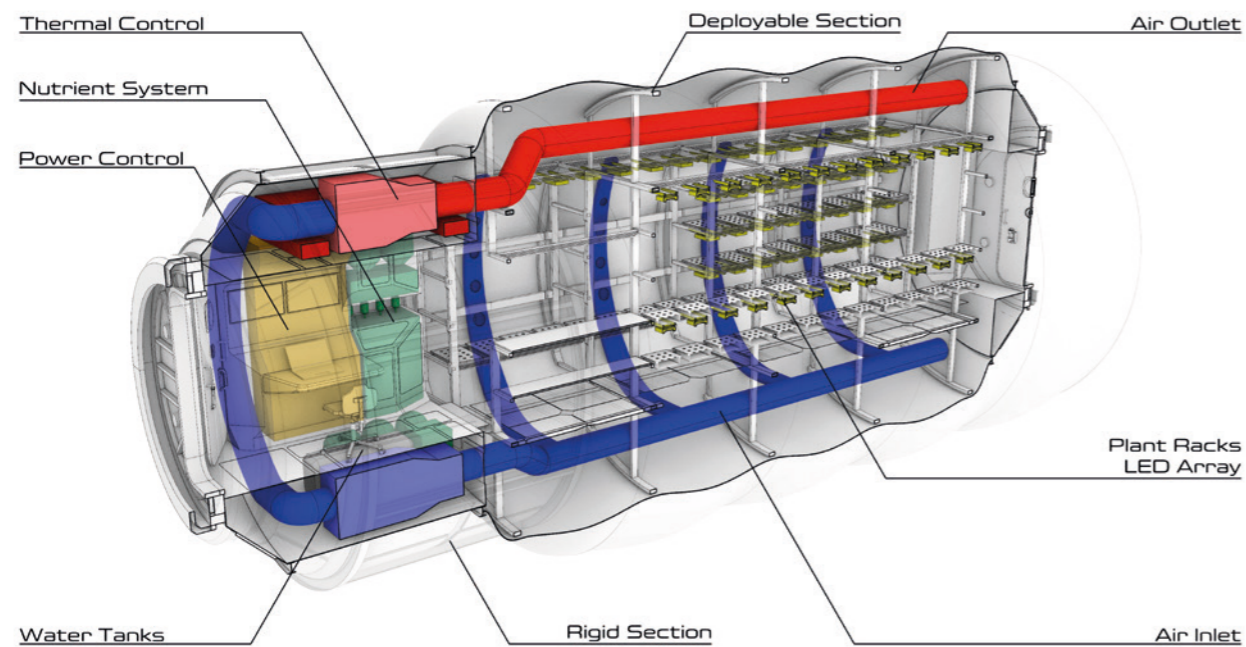


Main structural design concept of the EDEN Module for a Moon habitat. Deployable sequence is displayed; Primary- and secondary structure elements are visible

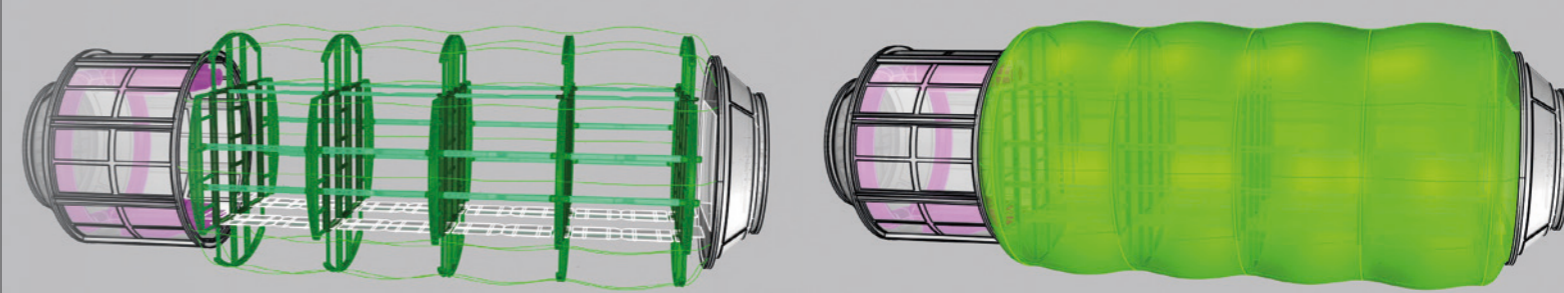
EDEN NEXT GENERATION

TRANSFORMING LESSONS LEARNED

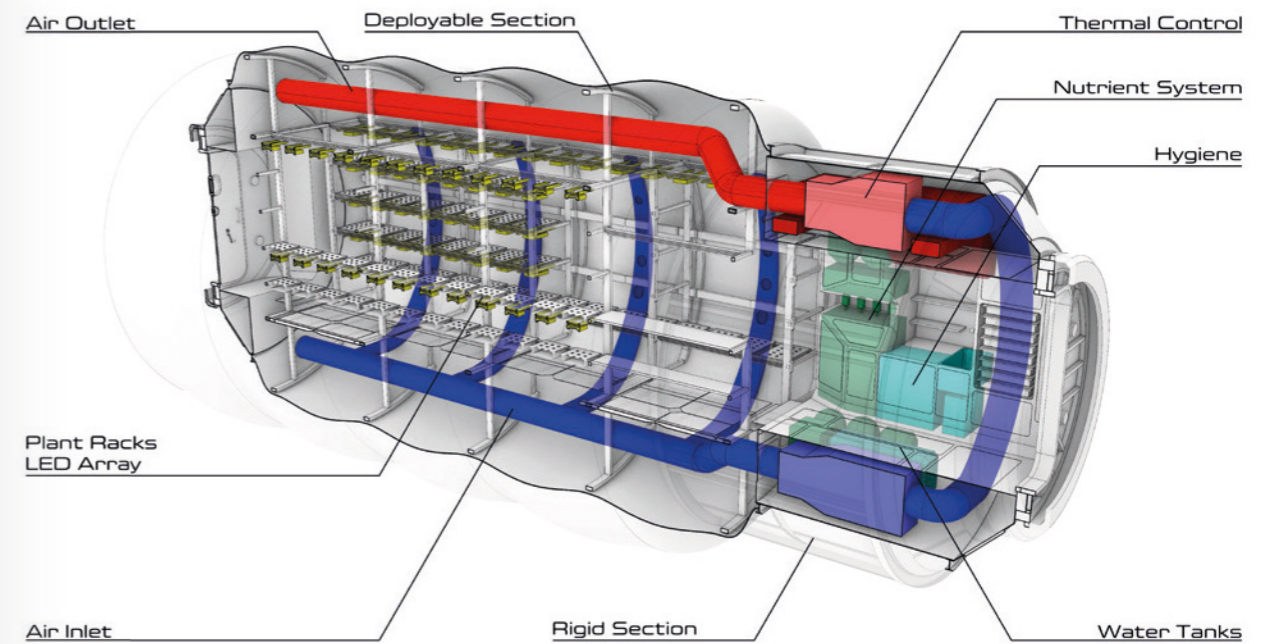
In the scope of the EDEN ISS space adaptation work packages, a preliminary design for a space-rated greenhouse for Moon and Mars was designed. At the end of March 2019, project members from DLR, Liquifer and AresCosmo gathered for the design study. The design foresees a hybrid primary structure, consisting of a rigid service section, which houses the majority of the technical subsystems, and a deployable greenhouse, which would provide the large volume needed for plant cultivation.



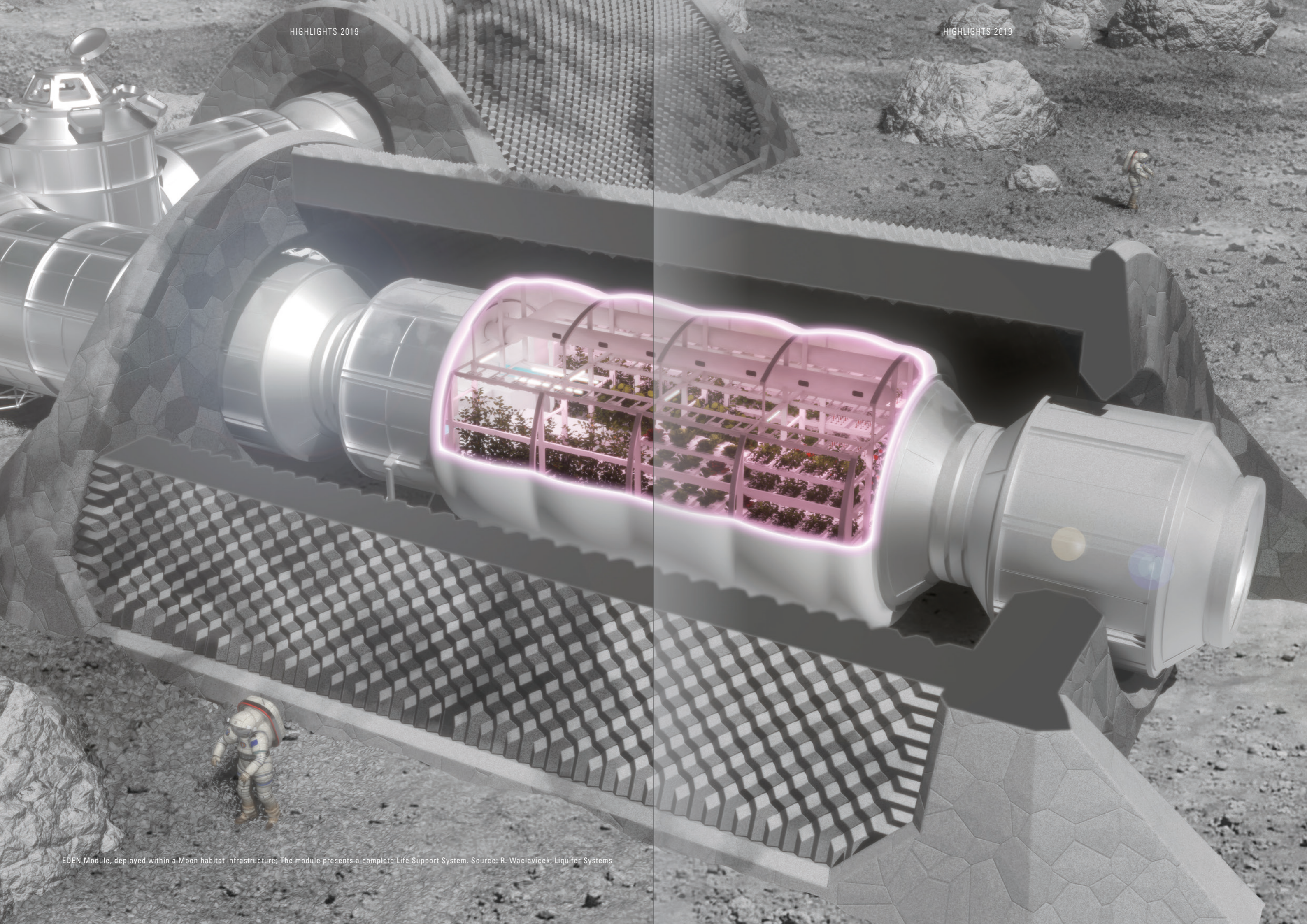
Left cut-away of the EDEN Module, incl. subsystem accommodation; Source: R. Wacławicek; Liquifer Systems



Based on performance values and lessons learned from the Antarctic EDEN ISS operations phase, the envisioned space food production system will provide up to 90 kg of fresh food per month for a crew of 6 astronauts (0.5 kg per astronaut per day) and could contribute to a significant percentage of the crew's caloric intake. It is the intention of the EDEN group to use this preliminary design as the baseline for further development activities, with the aim of building a space-rated ground demonstrator unit by 2025.



Right cut-away of the EDEN Module, incl. subsystem accommodation; Source: R. Wacławicek; Liquifer Systems



HUMANITARIAN TECHNOLOGIES

PROVIDING FRESH FOOD TO PEOPLE IN NEED.

In February 2019, the EDEN group attended the Humanitarian Technology (HumTech) days, organized by DLR in conjunction with multiple national and international humanitarian organizations. Following discussions at this workshop and previous work conducted, a new development project was initiated, called MEPA (Mobile Entfaltbare Pflanzen Anbauvorrichtung). The main goal is to develop a cost-effective, modular, transportable and rapidly deployable greenhouse system for use in humanitarian relief efforts. Possible deployment scenarios are after earthquakes, floods, droughts, or within refugee camps. The MEPA can provide fresh functional food in a mid-term perspective (after ~ six weeks of deployment).

Core part of the MEPA system will be the Seed Cultivation Coils (SCC), which are pre-seeded cultivation mats containing all the necessary components and nutrients needed for optimal plant cultivation. During 2019, a group of students performed preliminary design work, system calculations (e.g. thermal, power, structural), and two market analysis.



Fresh vegetables – a precious good in long-term crisis scenarios; Source: Karsten Moran for The New York Times

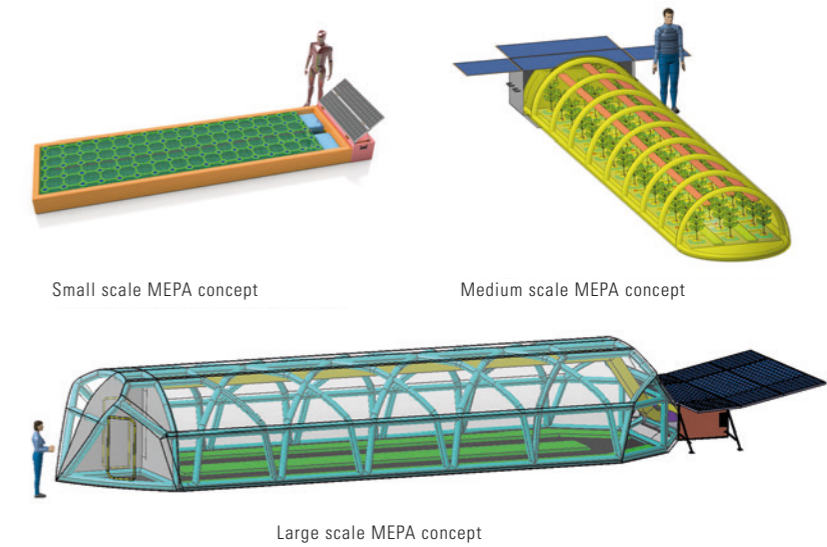


World Food Program helicopters deliver food to flood-stranded Cyclone victims in Mozambique; Source: Deborah Nguyen (WFP)

Refugee camp; Source: Courtesy of Project Earth 2



The participants of the HumTech Days, organized by DLR in February 2019



Small scale MEPA concept

Medium scale MEPA concept

Large scale MEPA concept

Three main MEPA design concepts for rapid food production within crisis scenarios



Discussing different topics for hydroponic plant cultivation and emergency food provision during the HumTech Days



Dr. Gerhild Bornemann (MEPA Project member, DLR-ME) during the open poster session



Transporting spare parts to the EDEN ISS platform, Source: Esther Horvath (AWI)



Markus Dorn preparing rock wool plugs for the upcoming seeding process, *Source: Esther Horvath (AWI)*

ESTHER HORVATH

EXCEPTIONAL PHOTOS FOR NATIONAL GEOGRAPHIC

During the maintenance & repair mission (Jan/Feb 2019), the team was accompanied by Esther Horvath, science photographer for the Alfred Wegener Institute. During her stay at the Neumayer Station III, she took exceptional pictures of the team during their work inside the greenhouse.

Since 2015, Esther has dedicated her photography to the polar regions, especially to the Arctic Ocean, documenting scientific expeditions and behind the scene science stories. She follows the work of multiple science groups that are working to better understand the changing polar regions. Esther's work has been featured in National Geographic, The New York Times, The Wall Street Journal, TIME, and GEO Magazine among others. The photo series that were shot during her stay in the greenhouse was published in National Geographic.



Prof. Dr. Anna-Lisa Paul (University of Florida) calibrating the multi-wave length sensors with a dedicated color plate; *Source: Esther Horvath (AWI)*



EDEN ISS Mission Control Center at the DLR Bremen (Institute of Space Systems); *Source: Esther Horvath (AWI)*



EDEN ISS fresh vegetables, *E. Horv. (AWI)*



Preparing the salad bar, *E. Horv. (AWI)*



Kitchen @ NM-III station, *E. Horv. (AWI)*



Inserting a lettuce seed into the rock wool plug, the plug is covered with cheese wax, *Source: Esther Horvath (AWI)*



Esther Horvath and Dr. Daniel Schubert during the photo session inside the EDEN ISS greenhouse



Close-up of the root system (pepper plant), *Source: Esther Horvath (AWI)*



EDEN ISS seed storage system (Antarctica); A total of ~60 different cultivars can be used for cultivation, Source: Esther Horvath (AWI)



Prof. Dr. Hansjörg Dittus (Executive Board DLR) during Botаниka exhibit opening ceremony



Mrs. Dittus, Dr. Paul Zabel and Prof. Dr. Hansjörg Dittus talking about the experience during the EDEN ISS isolation phase



The main exhibition room 'Plants in Space' at the Botanika (Bremen); Source: Annemarie Popp



From left to right: Stephan von Rundstedt (Bock BioScience), Dr. Daniel Schubert (DLR), Eva Quante-Brandt (Senator for Science and Education, Bremen); Dr. Annelie Dau (Botanika); Prof. Dr. Hansjörg Dittus (DLR), Dieter Taddigs (BAB), Petra Schäffer (Head of Botanika)

BOTANIKA

GRAND OPENING OF THE OPEN LABORATORY

7th of June 2019 marked the official opening of the Botanika exhibition with the title "Plants in Space". The exhibition was opened by Eva Quante-Brandt (Science Senator of the State Bremen), Prof. Dr. rer. nat. Hansjörg Dittus (Member of the Executive Board, DLR), and Petra Schäffer (Head of Botanika).

For this event, a dedicated educational showroom was created, called Open Laboratory. The exhibition is the highlight within the collaboration project between the DLR EDEN group, the company Bock BioScience, and the Botanika in Bremen. The project has been funded by the Bremen economic development fund (Bremer Aufbaubank). During the opening day, the EDEN group also presented a selection of dedicated photos of the first year of EDEN ISS operation in Antarctica.

The exhibit will remain a permanent part of the visitor center for the coming years and displays the different challenges of space greenhouses, the analogue test campaigns of the EDEN group, and future vertical farming projects.



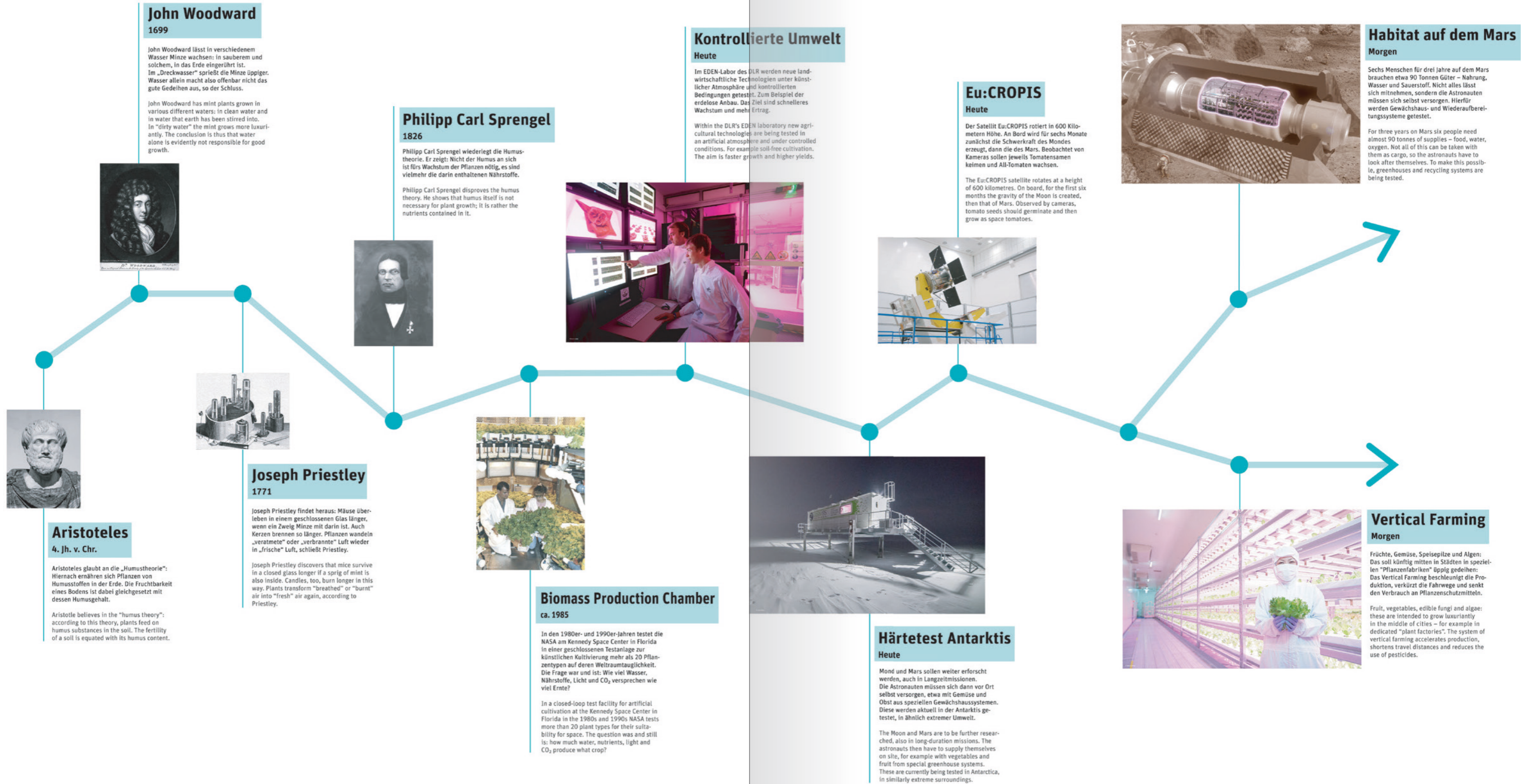
Photo exhibition of the EDEN ISS isolation campaign, displayed during the opening ceremony in the Japanese Garden of Botanika



Eva Quante-Brandt (Senator for Science and Education, Bremen) during opening ceremony



The main curators of the exhibition: Charlett Wenig (left) and Annemarie Popp (right)



Timeline poster, displayed in the Botanika exhibition, showing the evolution of plant sciences and plant cultivation in space; Source: Charlett Wenig & Annemarie Popp



Main press conference room of DLR



Huge media attention during both press conferences Here: TV camera teams in the DLR Mission Control Center (Bremen) for a live video feed from Antarctica



Dr. Daniel Schubert giving an outlook to the next development steps during the final EDEN ISS press conference



Dr. Paul Zabel presents the technical test results of the one year analogue mission in Antarctica



Final EDEN ISS press conference in August 2019; from left to right: Falk Dambowsky (DLR), Prof. Dr. Andreas Rittweger (Head of Institute of Space Systems DLR), Prof. Dr. Hansjörg Dittus (Executive Board DLR), Prof. Dr. Antje Boetius (Head of AWI), Dr. Paul Zabel (DLR), and Dr. Daniel Schubert (DLR)

EDEN ISS PRESS CONFERENCES

COMMUNICATING THE RESULTS

As 2019 marked the final project year, the EDEN team began disseminating the project results to the scientific community as well as to the general public. For this purpose, two press conferences were organized. The first one was organized in January and marked the return of Dr. Paul Zabel from his one year mission in Antarctica.

The second press conference was held in August. Here, the team presented the overall results of the technical validation tests, food quality & safety analysis, microbial investigations, and the psychological impact studies. During the press conference Prof. Dr. Boetius (Head of Alfred-Wegener-Institute), Prof. Dr. Dittus (Executive Board DLR), Prof. Dr. Rittweger (Head of Institute of Space Systems), Dr. Zabel (DLR), and Dr. Schubert (DLR) were available to answer the questions of the journalists. The media response was immense, as eight TV camera teams were present as well as multiple reporters from print, online, and radio media. During the meeting a future outlook of bio-regenerative life support systems was given, as the new EDEN Next Generation design was presented.



The first results were presented during the press conference, January 2019



Main press conference in January 2019, right after Dr. Paul Zabel returned from Antarctica

DESIGN COMPETITION

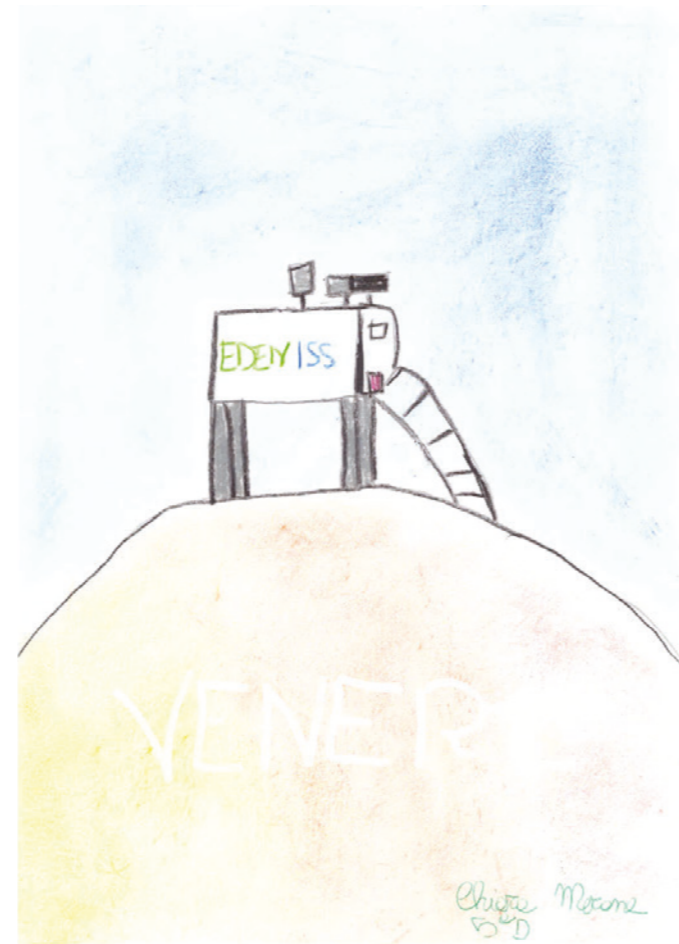
CHILDREN'S VIEW ON EDEN ISS

One element within the public engagement efforts of the EDEN ISS project was the organization of a children's design competition. Children (age 4-12) were invited to send in their view on the EDEN ISS project. Two separate design tasks were given: 1. Draw the outside of the greenhouse and place it somewhere you like. 2. Draw the inside of the greenhouse and imagine which crops are growing inside.

From the 85 submissions, each child received two Seed Transport Packages (STP) holding 10 original Antarctic lettuce seeds. This seed campaign, sponsored by the seed manufacturer Rijk Zwaan, was initiated during the deployment phase. The DLR team transported 50.000 lettuce seeds to Antarctica and back. Further the participants received a foldable EDEN ISS mock-up. The 15 winners of the design competition additionally received an EDEN ISS mission patch.



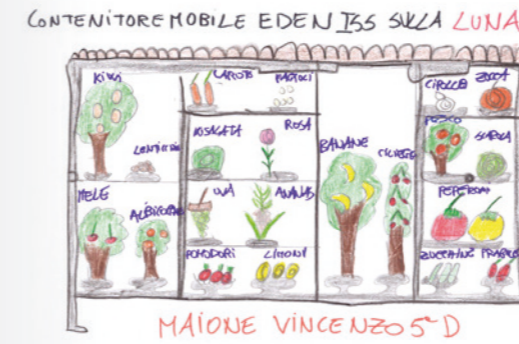
50.000 lettuce seeds were taken to Antarctica and back. They served as the basis for the seed outreach campaign



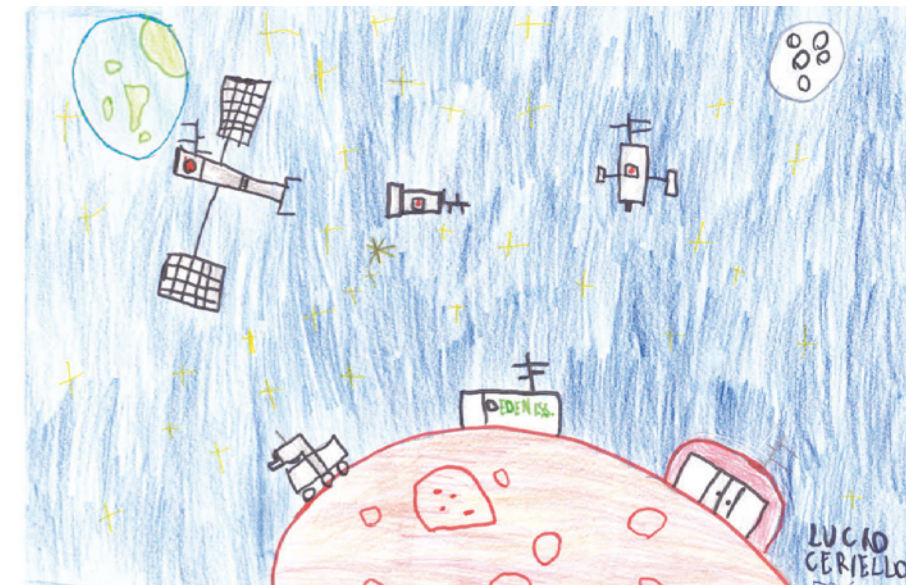
Chiara (age 10)



Elina (age 9)



Vincenzo (age 10)



Lucio (age 9)

Amelie (age 6)



Francesco (age 10)



Caroline (age 9)



Angela (age 10)

KEY FIGURES - 2019

JOURNALS

Zabel, P., Bornemann, G., Tajmar, M., Schubert, D., „Yield of dwarf tomatoes grown with a nutrient solution based on recycled synthetic urine”, Life Sciences in Space Research, 20, pp. 62-71, 2019.

Zeidler, C., Zabel, P., Vrakking, V., Dorn, M., Bamsey, M., Schubert, D., Ceriello, A., Fortezza, R., Simone, D. de, Stanghellini, C., Kempkes, F., Meinen, E., Mencarelli, A., Swinkels, G.-J., Paul, A.-L. and Ferl, R.J., “The Plant Health Monitoring System of the EDEN ISS Space Greenhouse in Antarctica During the 2018 Experiment Phase”, Frontiers in Plant Science, Vol. 10, p. 1457, 2019. DOI: 10.3389/fpls.2019.01457, ISSN 1664-462X.

Vrakking, V., Schubert, D., Zabel, P., Zeidler, C., Bamsey, B., Dorn, M., Boscheri, G., Ferl, R., Paul, A.-L. „EDEN ISS”, Chapter in Expeditions to Antarctica: ANT-Land 2018/19 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns; Reports on Polar and Marine Research; Issue 733, pages 52-67; Bremerhaven, Germany, 2019; ISSN: 1866-3192; DOI 10.2312/BzPM_0733_2019.

BOOK CONTRIBUTIONS

Zabel, P., Zeidler, C., „EDEN ISS: A Plant Cultivation Technology for Spaceflight” in Handbook of Life support Systems for Spacecraft and Extraterrestrial Habitats, Springer Verlag, 2019; doi:10.1007/978-3-319-09575-2_103-1; Buch ISBN: 978-3-319-10458-4.

Schlacht, I. L., Kolrep, H., Schubert, D., Musso, G., „Impact of plants in isolation: The EDEN-ISS Human Factors investigation in Antarctica” in Advances in Human Factors of Transportation, Springer Verlag, 2019; pp. 794-806, Advances in Intelligent Systems and Computing book series (AISC, volume 964).

PEER-REVIEWED CONFERENCE PROCEEDINGS

Zabel, P., Tajmar, M., „A System Dynamics Model of a Hybrid Life Support System”, 49th International Conference on Environmental Systems, 7-11 July 2019, Boston, Massachusetts, United States.

Zabel, P., Zeidler, C., Vrakking, V., Dorn, M., Schubert, D., „Crewtime in a Space Greenhouse based on the Operation of the EDEN ISS Greenhouse in Antarctica”, 49th International Conference on Environmental Systems, 7-11 July 2019, Boston, Massachusetts, United States.

Boscheri, G., Lobascio, C., Zabel, P., Marchitelli, G. and Saverino, A., „EDEN ISS Rack-like food production unit: results after mission in Antarctica”, 49th International Conference on Environmental Systems, 7-11 July 2019, Boston, Massachusetts, United States.

CONFERENCE PROCEEDINGS

Schlacht, I.L., Kolrep, H., Schubert, D., Musso, G. (in press) “Impact of Plants in Isolation: The EDEN-ISS Human Factors Investigation in Antarctica”, Proceeding of the 10th International Conference on

Applied Human Factors and Ergonomics (AHFE 2019), July 24-28 2019, Washington Hilton, Washington D.C., United States.

Müller,H., Schubert, D., Schlacht, I.(2019) „417 Days in Antarctica - Overwintering mission at Neumayer III with EDEN ISS greenhouse”, EuroMoonMars Workshop, 13th-15th May 2019, ESTEC, Netherlands.

Fortezza, R., Ceriello, A., De Simone, D., Schubert, D., Zabel, P., Zeidler, C., Vrakking, V., „The EDEN ISS Facility as platform for plant experiments in extreme environment”, AIDAA, 9-12 September 2019, Rome, Italy.

D. Schubert: „EDEN ISS - Ground demonstration of plant cultivation technologies for space”, CEG Project Workshop, 8.-9. May 2018, Cairo (Egypt)

Imhof, A. B., Hogle, M., Hoheneder, W., Waclavicek, R., Davenport, B., Schubert, D., Vrakking, V., Zeidler, C., Maiwald, V., Zabel, P., Dorn, M., Fiore, L., Rousek, T., Rossetti, V., „Greenhouse Design Concepts for Moon and Mars”, 70th International Astronautical Congress 2019, 21 - 25 October 2019, Washington D.C., United States.

Rettberg, P., Fahrion, J., Fink, C., Panitz, C., Rabbow, E., Schubert, D., Zabel, P., Beblo-Vranesevic, K., „Microbial Dynamics in the confined EDEN-ISS Greenhouse in Antarctica”, 70th International Astronautical Congress 2019, 21 - 25 October 2019, Washington D.C., United States.

Vrakking, V. „Design of a Controlled Environment Agriculture Greenhouse for arid regions”, 2nd CEG Project Workshop, 21 April 2019, Cairo, Egypt.

Vrakking, V. „Design of a modular closed-loop greenhouse for arid regions”, LCG/PMARS Workshop, 29 April 2019, Kenitra, Morocco.

Vrakking, V. „Overview of the EDEN ISS Project: Design and Operation of an Antarctic greenhouse”, LCG/PMARS Workshop, 29 April 2019, Kenitra, Morocco.

INVITED TALKS

Zabel, P., „Bio-regenerative Life Support Systems for Human Space Exploration”, Technical University Dresden, 18.06.2019.

Zabel, P., „Projekt Eden-ISS: Ein Jahr im ewigen Eis”, Zeiss Planetarium Berlin, 07.06.2019.

Zeidler, C., NASA’s Autonomy and Robotics to Space-based Crop Production Systems Workshop; Kennedy Space Center (Florida); 06.-07.08.2019.

Zabel, P., „Ein Jahr leben und arbeiten als Gärtner auf dem weißen Kontinent”, Universität Kassel, 10.12.2019.

Schubert, D.: „EDEN ISS: Analogue Testing of Plant Cultivation for Space”, Institute of Robotics and Mechatronics, DLR, Munich, 15.03.2019

Schubert, D.: „Antarktis-Gewächshaus EDEN ISS - Vorbereitung für zukünftige Habitate auf Mond und Mars”, Überseemuseum, Bremen, Januar 2019

Schubert, D.: „Vom Südpol ins Weltall - Gemüseanbau in der Antarktis”, Seminarreihe zu Alexander von Humboldt, Evangelische Bildungshaus Rastede, Rastede, 14.04.2019

Schubert, D.: „EDEN ISS: Analogue Testing of Plant Cultivation for Space”, University Skoltech, Moscow, Russia, 16.12.2029

Schubert, D.: „Vom Südpol ins Weltall - Gemüseanbau in der Antarktis”, Rotary Club Waldsrode, Wadsrode, 07.11.2019

DIPLOM-/ MSC.-/ BSC.-THESIS

Urte Clausen: „Analyse der optimalen Substrat- und Düngerzusammensetzung für Radieschen in einer mobilen entfaltbaren Pflanzenanbaueinheit”; Fachbereich 1 - Technik, Hochschule Bremerhaven; Master Thesis; 2019.

Paul Große Maestrup: „Auslegung des Energieversorgungssystems einer mobilen, entfaltbaren Pflanzenanbaueinheit für den Einsatz in Krisenregionen und Wüsten”; Abteilung Maschinenbau; Fakultät 5: Natur und Technik, Hochschule Bremen; Bachelorarbeit; 2019.

Nane Fritz: “Gardening in Ruins. Export plan on the application of transportable and inflatable plant cultivation units in crisis regions”; International Business School, Hanze University of Applied Sciences Groningen; Bachelor Thesis; 2019.

Jonas Bischof: „Ermittlung der optimalen CO2-Düngung mittels chemisch gebundener Kohlenstoffdioxid Medien für den Kultivierungsprozess innerhalb der MEPA(Mobile Entfaltbare Pflanzenanbaueinheit)”; Abteilung Maschinenbau; Fakultät 5 Natur und Technik, Hochschule Bremen; Bachelor Thesis; 2019.

Waldemar Cekusov: „Systementwicklung und Design einer Mobilen Entfaltbaren Pflanzen Anbaueinheit für den Einsatz in Krisenregionen”; Bereich: Ingenieurwissenschaften; Richtung: Entwicklung und Konstruktion; Jade Hochschule Wilhelmshaven Oldenburg Elsfleth, Bachelor Thesis; 2019.

Alina-Sophie Klix: „Systemanalyse einer Pflanzenkultivierungsmatte für den Anbau von Nahrungsmitteln”; Studiengang Bionik (B.Sc.), Fachbereich Maschinenbau -Bocholt, Westfälische Hochschule; Bachelor Thesis; 2019.

Julian Gautzsch: „Entwicklung und Konstruktion eines Wassermanagementsystems für eine autarke entfaltbare Pflanzenanbaueinheit”; Fachbereich Ingenieurwissenschaften, Jade Hochschule Wilhelmshaven; Masterarbeit; 2019.

Giulia Sales: „Nutrition supply in humanitarian markets - A market analysis for MEPA-units”; International Business & Management; Fontys University of Applied Science, Netherlands; Bachelor Thesis; 2019.

Florian Rzepka: „Analyse und Berechnung des thermischen Systems eines mobilen Gewächshausmoduls” Institut für Energietechnik, Fachgebiet für Maschinen und Energieanalagentchnik, Technische Universität Berlin, Master Thesis

Tejal Thakore: „Design and Analysis of a Deployable Greenhouse Structure for Martian Environment”, Universität Bremen, Fachbereich 04: Produktionstechnik, Maschinenbau und Verfahrenstechnik, Master Thesis, 2019.

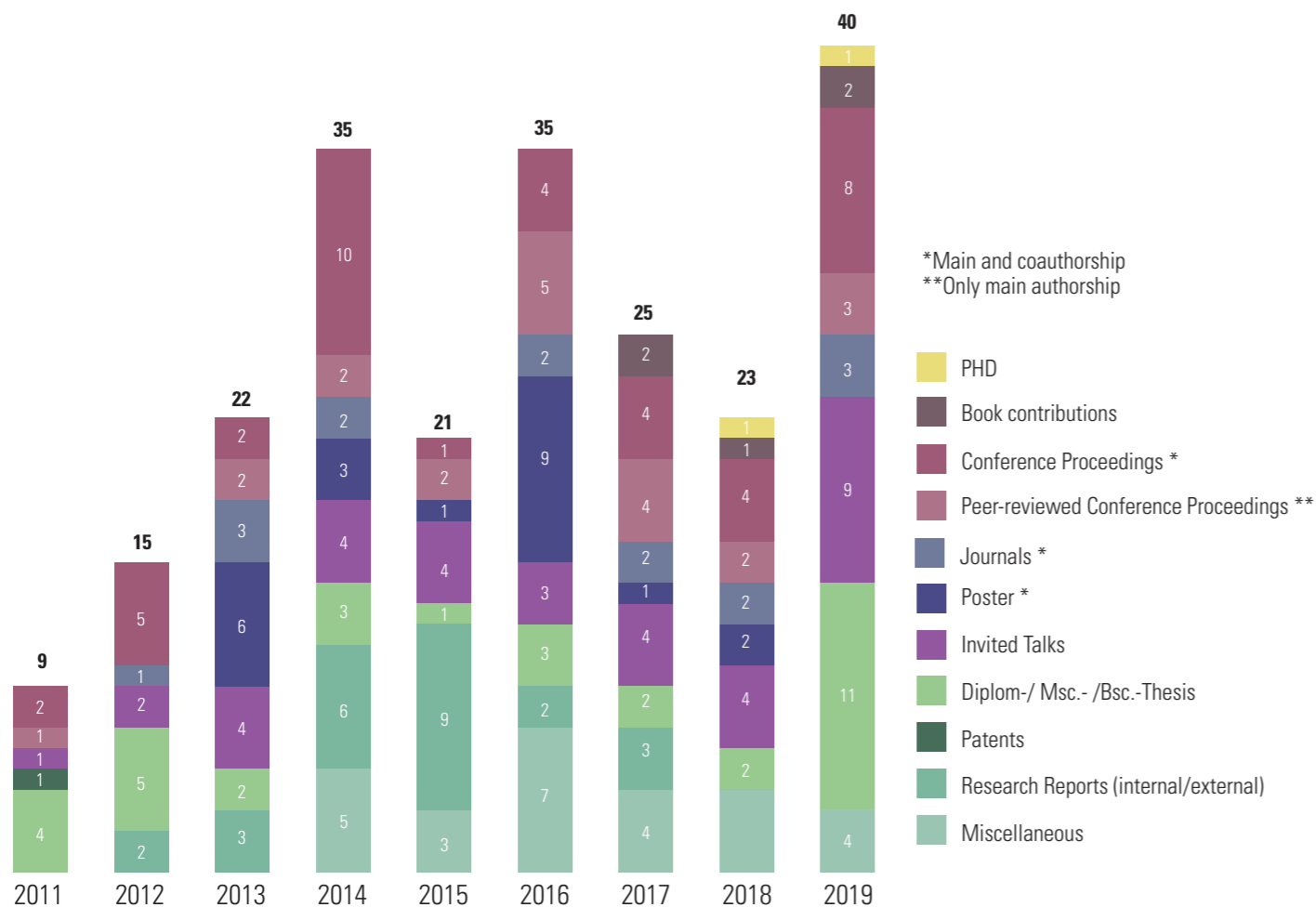
Matthias Abeln: Redaktionsleitfaden für eine Assisted Reality-Anwendung - Beispielhafte Umsetzung für das EDEN ISS-Projekt des Deutschen Zentrums für Luft- und Raumfahrt; Studiengang Technische Redaktion (B.Eng.), Fachbereich Elektro und Informationstechnik, Hochschule Hannover; Bachelor Thesis; 2019.

PHD THESIS

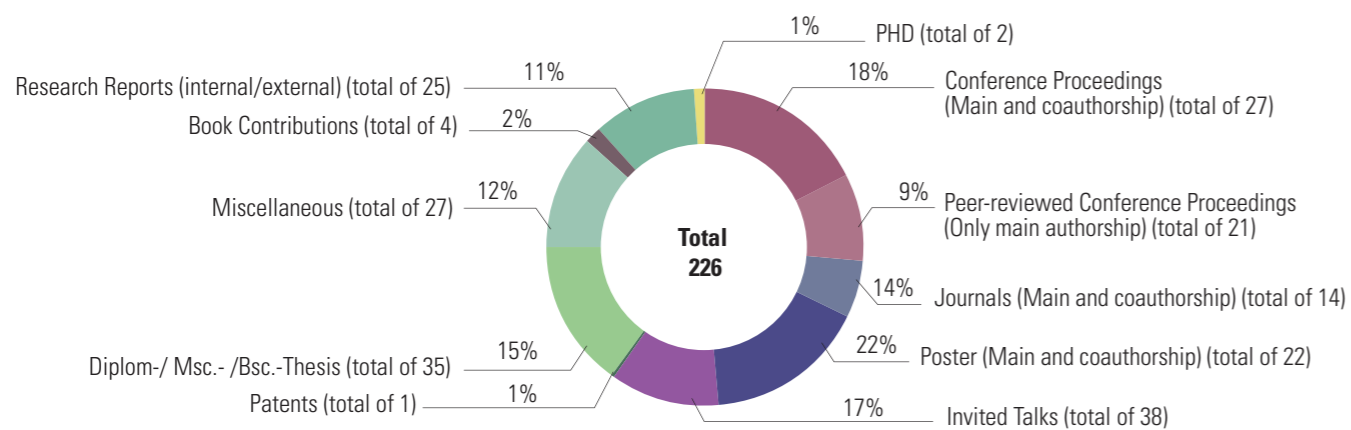
Zabel, P., „An investigation of the dynamic behavior of a hybrid life support system and an experiment on plant cultivation with a urine-derived nutrient solution”, PhD dissertation, TU Dresden, 2019.

SUMMARY KEY FIGURES (2011-2019)

PUBLICATIONS & KEY FIGURES 2011-2019



TOTAL PUBLICATIONS & KEY FIGURES 2011-2019



THE EDEN 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:



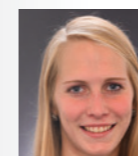
Alina-Sophie Klix is a biomimetics student from the Westfälische Hochschule in Bocholt. She has been working on the MEPA project of the EDEN initiative. Alina first completed her three-month practical phase at DLR and then wrote her bachelor thesis "System Analysis of a Plant Cultivation Mat for the Growing of Food".



Florian Rzepka has a Master's degree in Renewable Engineering from TU Berlin. He served as a Master's Thesis student at DLR, Bremen from March to August 2019, his task was the analysis and calculation of the thermal system of the mobile greenhouse module MEPA.



Julian Gautzsch was a master mechanical engineering student from the Jade-Hochschule in Wilhelmshaven. In the EDEN team he worked on his master thesis with the title: "Development and construction of a water management system for a self-sufficient deployable plant cultivation unit". He finished his master thesis in September 2019.



Nane Fritz conducted a market research for the EDEN team and explored the application of the transportable plant cultivation unit MEPA in regions affected by natural disasters. She finished her bachelor thesis in July 2019 and graduated with a Bachelor of Business Administration from the Hanze University of Applied Sciences Groningen.



Tejal Thakore holds a MSc. in Space Engineering from TU Bremen. During her time at DLR she carried out a literature study on space greenhouses and completed her Master thesis on the design of a deployable greenhouse structure for future Mars missions, laying the groundwork for a transition of the EDEN ISS analogue greenhouse facility towards a future planetary greenhouse.



During his studies in technical editing at the University of Applied Sciences and Arts Hannover, Matthias Abeln did a three month internship in the EDEN group. Here he had many exciting tasks, among others in the field of public relations. His tasks included, for example, the creation and preparation of texts used for the exhibition in the Botanika as well as the creation of presentation videos for press conferences and a trade fair.



Paul Große Maestrup is an aerospace engineering student at the Bremen University of Applied Science. During his time at DLR he worked on his bachelor's thesis on the electrical power subsystem of the MEPA project. After completing his bachelor's degree, he intends to continue with a master's degree with focus on space technology.



Giulia Sales is an international business and management student working on her bachelor's degree at the Fontys University in Venlo, Netherlands. During her time at the DLR, she wrote her bachelor thesis, analyzing the market feasibility for the terrestrial spin-off project of MEPA-units. Her focus was set on the analysis of humanitarian markets, specifically refugee camps.



Urte Clausen has a Master's degree in Biotechnology from the Hochschule Bremerhaven. During her work in the EDEN team she developed root bags for the Seed Cultivation Mat. Her focus was set on the analysis of different substrates and fertilizers for the cultivation of radish. Urte works as a scientific-technological employee at the Hochschule Bremerhaven, and furthermore, she supports the EDEN team at the MEPA-project.



Jonas Bischof is studying aerospace engineering at the Bremen University of Applied Sciences and did his bachelor thesis from March to June at DLR with a focus on CO2 fertilization. He built a test rig and carried out various experiments with chemically bound carbon dioxide media.



Waldemar Cekusov is a mechanical engineering student working on his bachelors at the Jade Hochschule Wilhelmshaven Oldenburg Elsfleth. He served as a Bachelor's Thesis student at DLR from December to September 2019, his topic System development and design of a mobile inflatable plant cultivation unit for use in crisis regions.

IMPRESSIONS 2019

A FULL YEAR OF WORK...



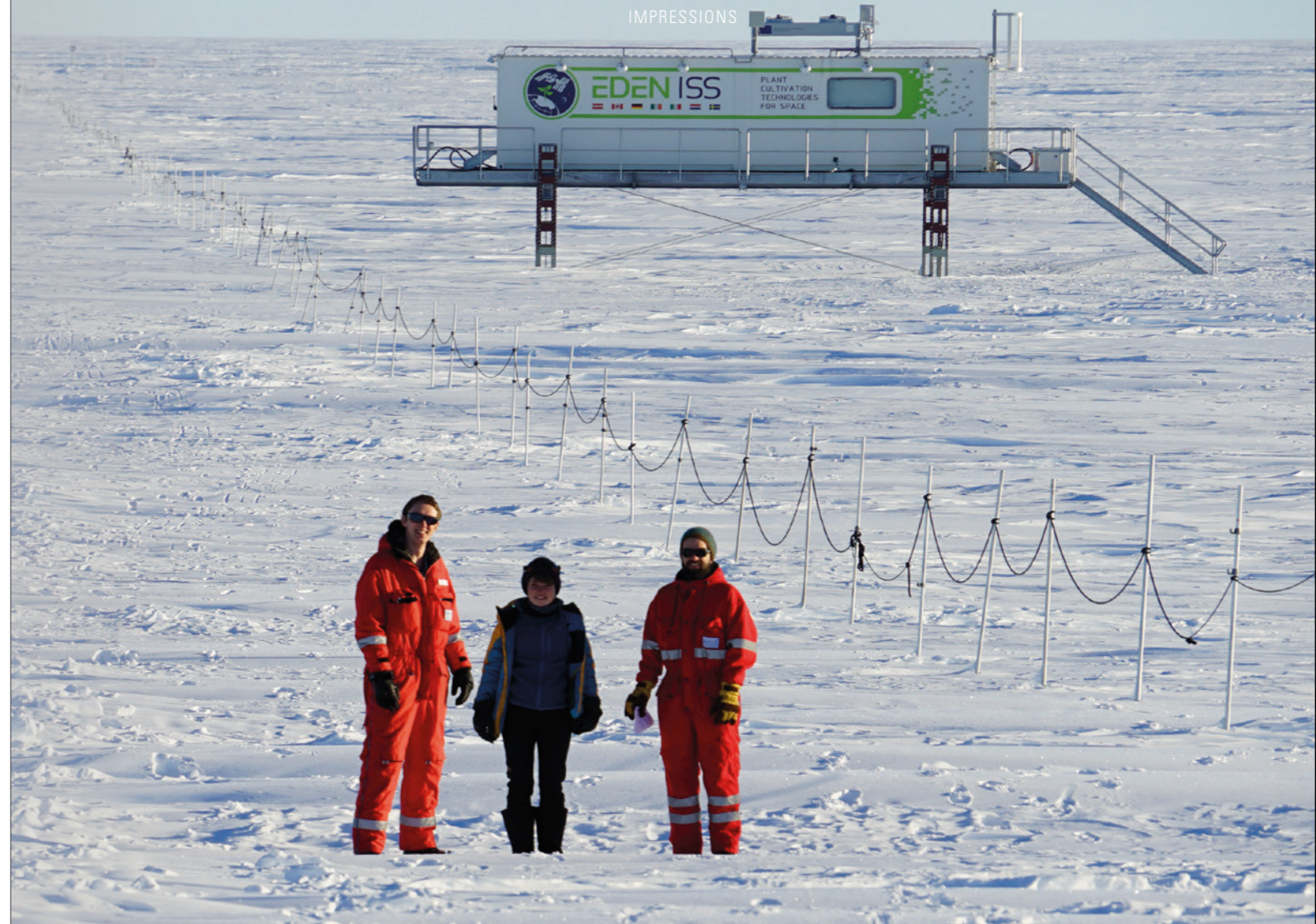
After a long day of work, some billiard in the social room of the station. In the background the clear view to the EDEN ISS research platform.



Dr. Daniel Schubert inside the Neumayer Station III during maintenance mission



Markus Dorn doing some acrobatics on the EDEN ISS spare part container



Vincent Vrakking (left), Fine Stakemann (middle), and Conrad Zeidler (right) during a photo-op in front of the EDEN ISS research platform



Prof. Dr. Rob Ferl (University of Florida) visiting the EDEN ISS greenhouse on a sunny day



Visiting the Antarctic post box near the station



Prof. Dr. Otmar D. Wiestler (President Helmholtz Association), followed by Dr. Daniel Schubert during the in-bound flight to NOVO runway (Antarctica)



Improved nutrient stock solution tanks were implemented into EDEN ISS



New rock wool holders during cleaning process inside the station's laboratory

A quick visit at the Kohnen-Station (AWI) during the out-bound flight; Location: Dronning Maud Land (Antarctica), 2892 m above sea level



The "Oasis" at the Novolazarevskaya Station (Russia). Due to bad weather conditions, Dr. Daniel Schubert had to spend seven days at the station, waiting for the final flight to Cape Town



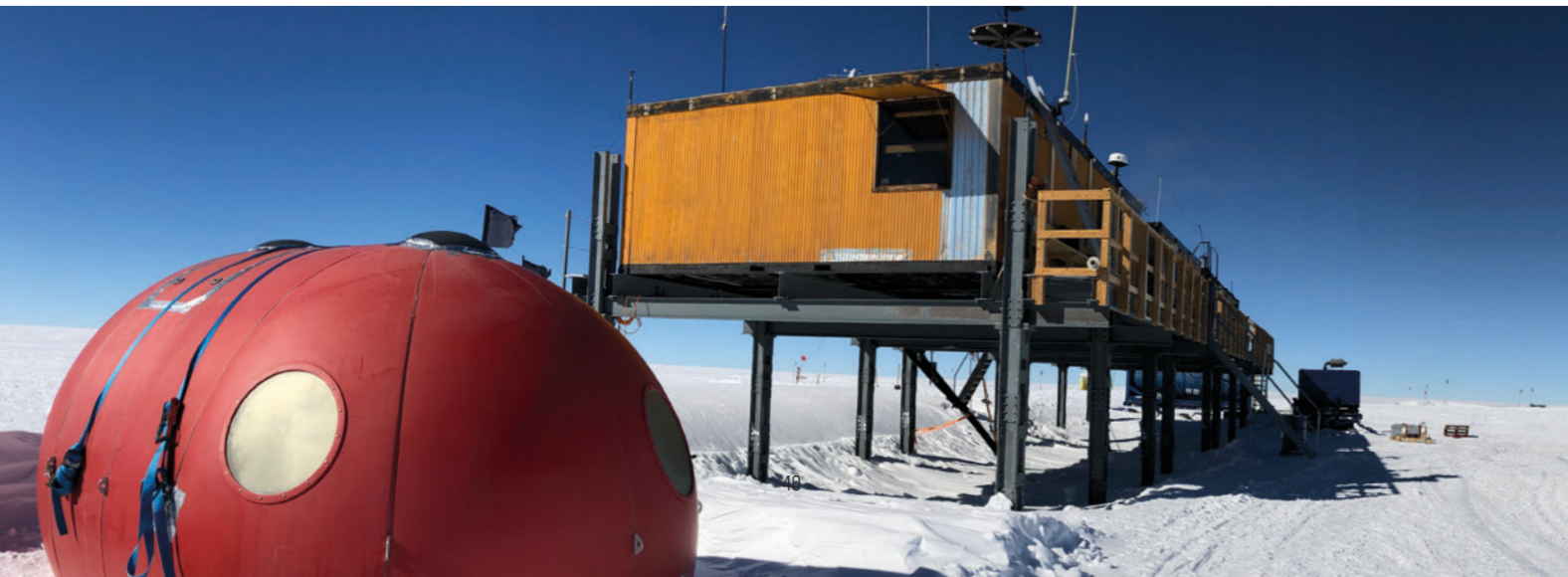
Cucumber roots inside one tray during final cleaning up



First dinner in Cape Town, waiting for the inbound flight to Antarctica



Conrad Zeidler and Dr. Daniel Schubert observing Markus Dorn during the photo session of Esther Horvath (AWI)





Kohlrabi harvest



Esther Horvath (AWI) taking a selfie with the EDEN team



Thumbs up! (observation cam EDEN ISS service section)



Main social room at the Russian Novolazarevskaya Station



Birthday celebration of Prof. Dr. Rob Ferl (University of Florida) during the stay in Antarctica; Chocolate cake it is!



Prof. Dr. Rob Ferl (University of Florida) during EVA



Dr. Daniel Schubert visiting the EDEN ISS platform during storm



Cleaning the plant trays during the maintenance mission inside the station's laboratory



Greetings from the rooftop of the EDEN ISS greenhouse system (task: exchanging one of the fans of the free cooler)



Driss Zejli giving an introduction at the second DLR workshop of the PMARS project in Kenitra, Morocco



Dr. Paul Zabel during a EDEN ISS spin-off workshop at the University of Wageningen (The Netherlands)

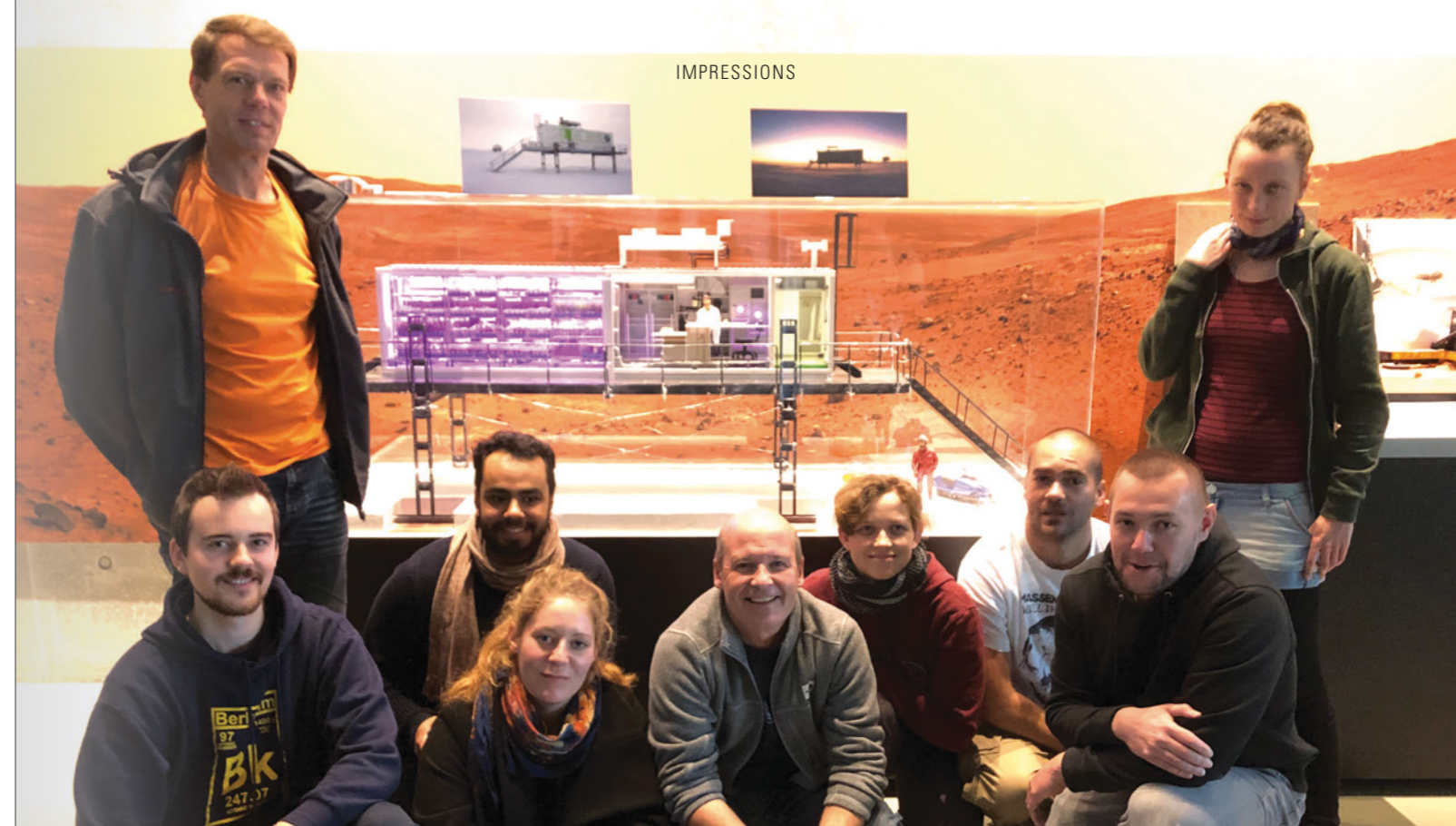


Participants during the EDEN ISS spin-off workshop at the University of Wageningen (The Netherlands).



Touring the Green Energy Park in Ben Guerir, Morocco during the second workshop of the PMARS project

Audience attending the second international workshop of the PMARS project in Kenitra, Morocco



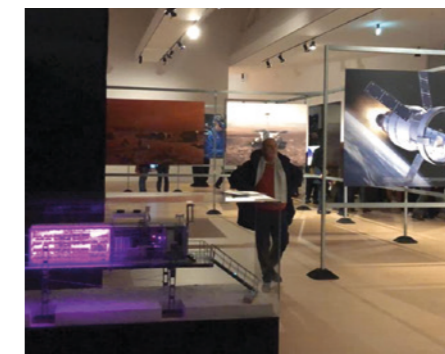
The new AWI overwintering team for 2020 during their visit of DLR Institute of Space Systems (Bremen); From left to right: Dr. Klaus Guba, Noah Trumpik, Wanderson de Almeida Santos, Anna-Marie Jörss, Roman Ackle, Ina Wehner, Mario Beyer, Andreas Oblender, Julia Lofftield



Official flyer of the M9 Museum in Venezia Mestre (Italy)



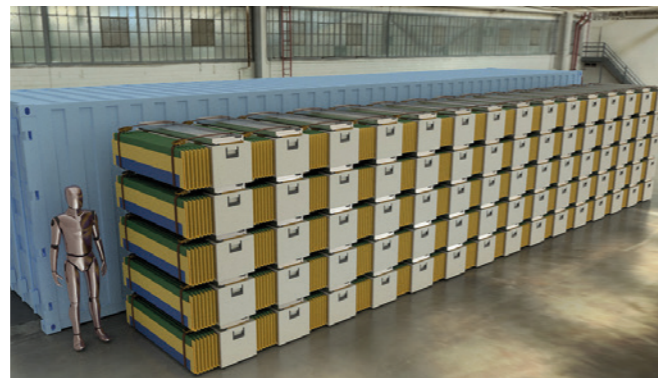
Dr. Irene Schlacht (middle) during the psychological briefing with Roman Ackle, AWI (left) and Dr. Klaus Guba, AWI (right)



EDEN ISS mock-up during 'Lunar City' exhibition in Venezia Mestre (Italy)



HumTech Days 2019 at DLR Oberpfaffenhofen; Discussing technological solutions for an adequate humanitarian crisis management



The MEPA design in the transport configuration. 75 units can fit into one 40' container



Vincent Vrakking visited the THW open field exhibition as prep. work for the MEPA project



Inflatable tents – one solution for the upcoming MEPA project; Picture taken during THW open field exhibition



Dedicated documentary about the EDEN ISS project (Galileo, Pro7, 05.02.2019)



Dr. Daniel Schubert is giving an interview for German television during Botanika opening ceremony

Tomaten wachsen ohne Erde

Botanika zeigt in ihrem Entdeckerzentrum die Ausstellung „Pflanzen im Weltraum“

VON MARTIN KOWALEWSKI

Bremen – Bald werden sie Früchte tragen. Die Tomatenpflanzen wachsen seit drei Wochen ohne Erde. In einer Metallkiste mit Glasscheibe stecken ihre Wurzeln, darüber entfalten sich die grünen Stängel und Blätter. Mit dem Ausstellungsprojekt „Pflanzen im Weltraum“ präsentiert das Science-Center Botanika jetzt in seinem Entdeckerzentrum ein Minilabor und weitere Exponate, die zeigen, wie Nahrung im Weltraum und abgeschnittenen Bereichen erzeugt werden kann.

Die Zuschauer sehen, wie groß die Wurzeln der Tomatenpflanzen inzwischen geworden sind, als in dem Kasten das Licht angeht. Ein Surren ist zu hören. Die Wurzeln werden von unten mit Wasser angespritzt. Darin werden Nährstoffe gelöst. Durch eine Zeitschaltuhr passiert das alle fünf Minuten. Das Wasser kommt aus einem Tank unter den Pflanzen. Was die Wurzeln an Wasser nicht aufnehmen, setzt sich ab und landet wieder im Tank. Rund um die Uhr bekommen die Pflanzen eine optimale Beleuchtung durch eine LED-Lampe.

Das Minilabor wird von der Botanika und dem Projekt „Eden“ des Deutschen Luft- und Raumfahrtzentrums (DLR) betrieben. Das Projekt erforscht, wie Pflanzen auf Raumfahrtmissionen gedeihen können. „Die Umgebung der Pflanzen ist steril. Sie



Daniel Schubert, Leiter des Projekts „Eden“, steht vor dem Mini-Labor in der Ausstellung „Pflanzen im Weltraum“ in der Botanika.

FOTO: KOWALEWSKI

können sich keine Krankheiten einfangen“, sagt Projektleiter Daniel Schubert. „Eden“ hat ein Labor in Bremen und seit 2018 auch das „Eden-ISS“-Labor an der Antarktis-Station Neumeyer III des Alfred-Wegener-Instituts (AWI).

Botanika und „Eden“ wollen gemeinsam mit dem Minilabor in der Ausstellung forschen. Es gibt bereits knifflige Aufgaben zu lösen. Mit Gemüse funktioniere alles gut, sagt Schubert. Mit Erdbeeren hatte man in der Antarktis Probleme. „Sie haben keine Früchte abgewor-

fen, vielleicht war die Kältephase zu kurz“, fährt der Projektleiter fort. In der Botanika ist bereits ein Salat in dem Minilabor gewachsen. „Den haben wir bereits gegessen“, sagt Annelie Dau, die im Wissenschaftszentrum die „Grüne Schule“ leitet. „Die Pflanzen wachsen extrem schnell. Man kann es wirklich jeden Tag sehen.“ Was nach den Tomaten gepflanzt wird, ist noch unklar. Möglicherweise sind es Salat-Samen, die die US-Raumfahrtbehörde Nasa zur Verfügung gestellt hat. Auch um das Minilabor herum gibt es

spannende Dinge zu sehen. Darunter sind In-Vitro-Kulturen: In einer keimfreien Nährlösung wachsen aus Pflanzenteilen ganze Pflanzen heran, genauer gesagt: Obstsorten in einem Geliermittel aus Algen. Zur Verfügung gestellt wurden die Kulturen vom Bremer Gartenbaubetrieb und In-Vitro-Spezialisten „Bock Bio Science“. „Wir forschen intensiv daran, wie man die Welt auch übermorgen noch ernähren kann“, sagt Stephan von Rundstedt, geschäftsführender Gesellschafter. Hansjörg Dittus aus dem Vorstand des

Fotos im Foyer

Die Dauerausstellung „Pflanzen im Weltraum“ ist im Entdeckerzentrum der Botanika (Deliusweg 40) zu sehen. Im Foyer sind zudem Fotos und ein Modell zum Thema „Eden-ISS-Labor“ für einige Tage ausgestellt. Die Botanika öffnet montags bis freitags von 9 bis 18 Uhr, sonntags, sonntags und feiertags von 10 bis 18 Uhr. Der Eintritt kostet 10,50 Euro.

Fotos auf www.kreiszeitung.de

One of the press articles regarding the Botanika exhibition (Kreiszeitung-Syke-Weyhe-Stuhr, 08.07.2019)



Opening ceremony of the Botanika exhibition 7th of June



Petra Schäffer (Head of Botanika) during the opening ceremony



Eva Quante-Brandt (Senator for Science and Education, Bremen) holding dedicated astronaut food in her hand during the visit of the exhibition 'Plants in Space' (Botanika)

EDEN group picture during the opening ceremony in the Japanese Garden of Botanika.



EDEN ISS Photo exhibition in the Japanese Garden of Botanika



Strawberry clones, which were flown to Antarctica; Displayed during the Botanika exhibition



Stephan von Rundstedt together with Dr. Uwe Nixdorf (Vice Director of AWI) during the opening ceremony



EDEN ISS ist ein Projekt der International Space Station (ISS) und wird von der ESA, der NASA, der Roscosmos, der CNES, der CSA, der ISRO, der JAXA und der KARI durchgeführt. Die EDEN ISS ist ein Experiment zur Erforschung der Auswirkungen von Schwermetallen auf die menschliche Gesundheit im Weltraum. Die EDEN ISS ist ein Experiment zur Erforschung der Auswirkungen von Schwermetallen auf die menschliche Gesundheit im Weltraum. Die EDEN ISS ist ein Experiment zur Erforschung der Auswirkungen von Schwermetallen auf die menschliche Gesundheit im Weltraum.

The Japanese Garden of Botanka, during the opening ceremony, showing the a photo taken during the deployment phase of the EDEN ISS research platform in Antarctica



EDEN group during social event at the Ratskeller (Bremen)



Dr. Paul Zabel receiving his doctoral hat from Dr. Oliver Romberg (Department Head of System Analysis Space Segments, DLR)

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.

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