

FROM ANTARCTICA TO THE MOON

Developing Plant Cultivation Technologies for Space at DLR





INTRODUCTION



Our Research Group



Planetary Infrastructures

Bioregenerative Life Support Systems (BLSS)



In-Situ Resource Utilization (ISRU)



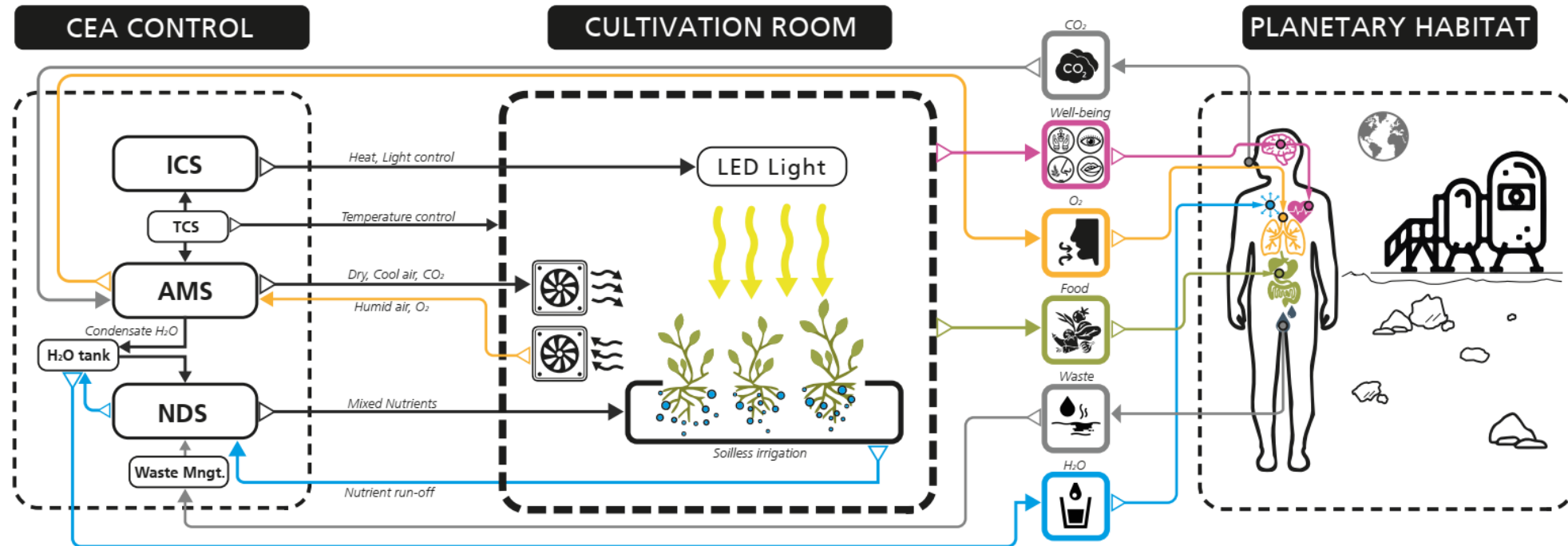
Habitat Infrastructure Design



- System analysis & concurrent engineering studies
- Hardware development, design & procurement
- Assembly, integration & (analogue field) testing
- Operation & technology transfer (e.g. vertical farming)

Our Research Topic

Bio-regenerative Life Support Systems



- *Input:* CO₂-rich air (respiration), water (recycled grey water), nutrients, light
- *Output:* O₂-rich air, water (dissolved in air as RH), nutritious biomass, mental well-being
- *Goal:* Creating a symbiosis between plants and humans

Our Research Projects

EDEN ISS & LUNA, LAM-GTD

EDEN ISS



A container-sized plant cultivation test facility in Antarctica. The system was built to demonstrate and validate key technologies and procedures necessary for safe food production within a (semi-) closed system.

EDEN LUNA



Life extension of the EDEN ISS system with fully redesigned subsystems and a refurbished container. Attached to the LUNA analog facility in Cologne, end-to-end operated by and DLR/ESA employees & astronauts.

LAM-GTD



LAM is the attempt to take BLSS one step closer to space. It is a cargo module which turns into a lunar greenhouse once it reaches the Moon. The GTD is developed with space standards and requirements in mind, but operated on Earth.



EDEN ISS

Project

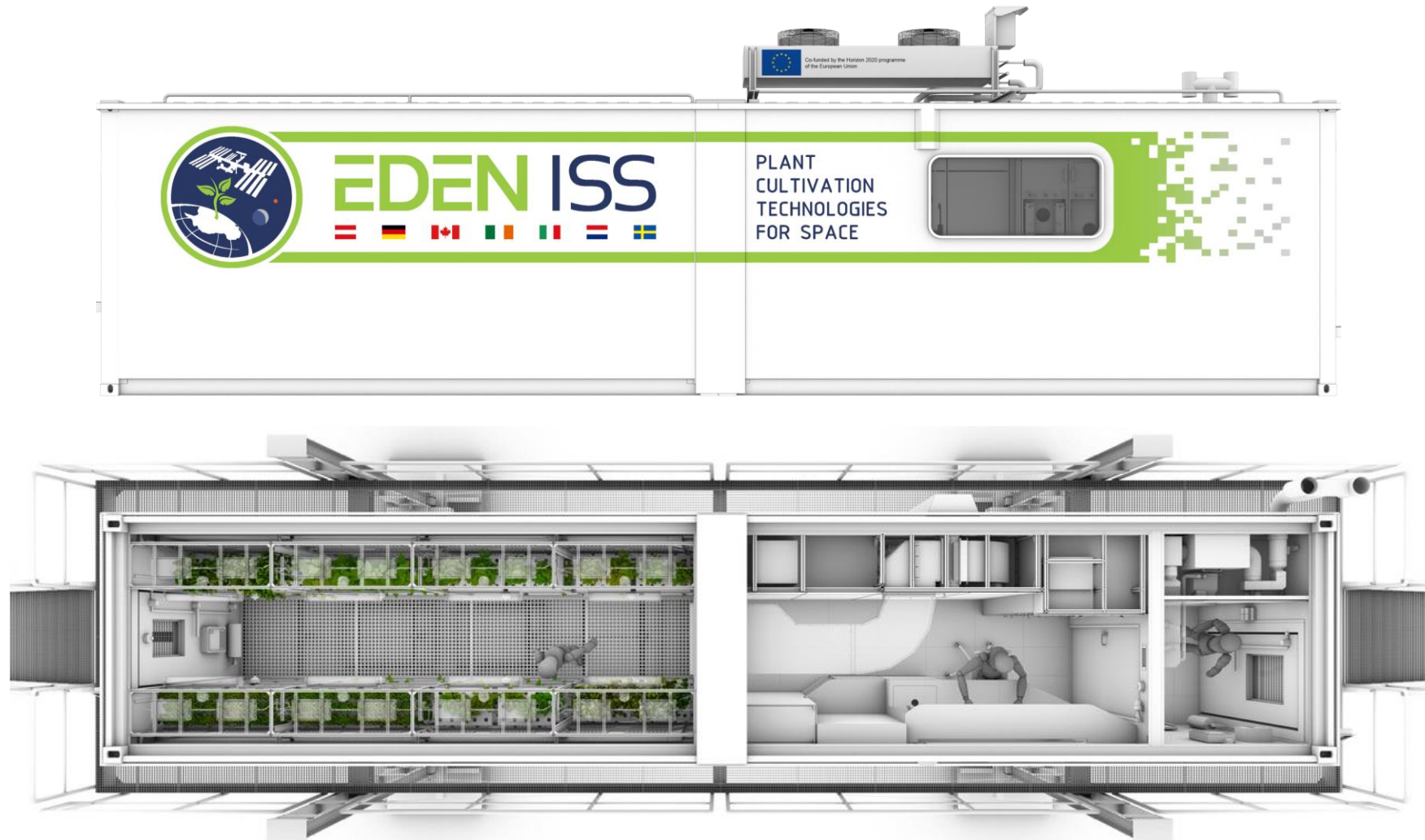


- First complex greenhouse analogue mission in Antarctica
- Tested at German Neumayer Station III
- Supplied 9+1 crew members
- 14 partners from different backgrounds (industry, universities, institutes)
- 8 countries involved
- Started in 2015, ended in 2022



- Test of critical plant cultivation technologies in relevant environment
- Humans-in-the-loop investigations
- Controlled by Mission Control Center (MCC) at DLR Bremen

System



- Independent biomass production under a semi-closed-loop environment
- Fast production cycles, high yields, low resource consumption

Subsystems

Controlled Environment Agriculture (CEA)

Nutrient Delivery System (NDS)



Illumination Control System (ICS)



Atmosphere Management System (AMS)



- *NDS* mixes macro- and micro-nutrients, dissolves them in water, delivers nutrients to plants
- *ICS* irradiates light in wanted parts of the electromagnetic spectrum
- *AMS* induces airflow, filters contaminants, recaptures water, measures & controls air conditions

Arrival in Antarctica



Operation in Antarctica



EDEN LUNA



EDEN luna



Image source: ESA/DLR

Infrastructure

LUNA Analog Facility



- An analogue facility for the preparation of future human and robotic missions to the Moon at DLR/ESA-EAC in Cologne
- Includes functional integration of external modules (i.e. EDEN LUNA, space suits, lander)
- Allows complex simulations for lunar surface activities (tools, processes, crew training, etc.)

Project

Ideas

- Refurbishing & upgrading EDEN ISS
- Astronauts-in-the-loop testing
- Preparatory step for the LAM-GTD

Advancement

- Improved CEA Technologies
- New command and data handling system
- EDEN Versatile End-Effector (EVE) Robotic System
- The C.R.O.P.® Bio-filter for urine processing
- A novel Machine Learning / Artificial Intelligence system for Anomaly Detection And Monitoring (ADAM)



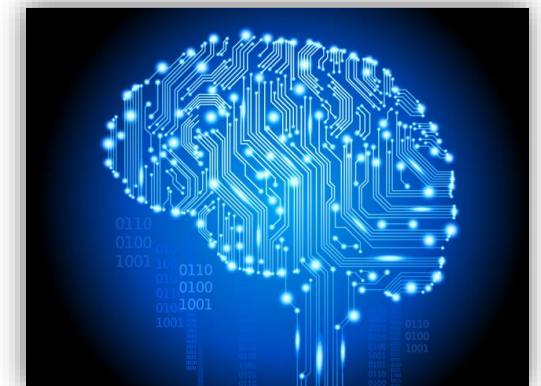
CEA Technologies



Robotic System



Urine Filters

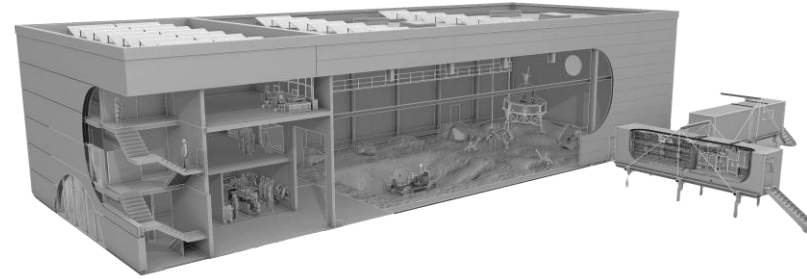


AI / ML Risk Mitigation

System



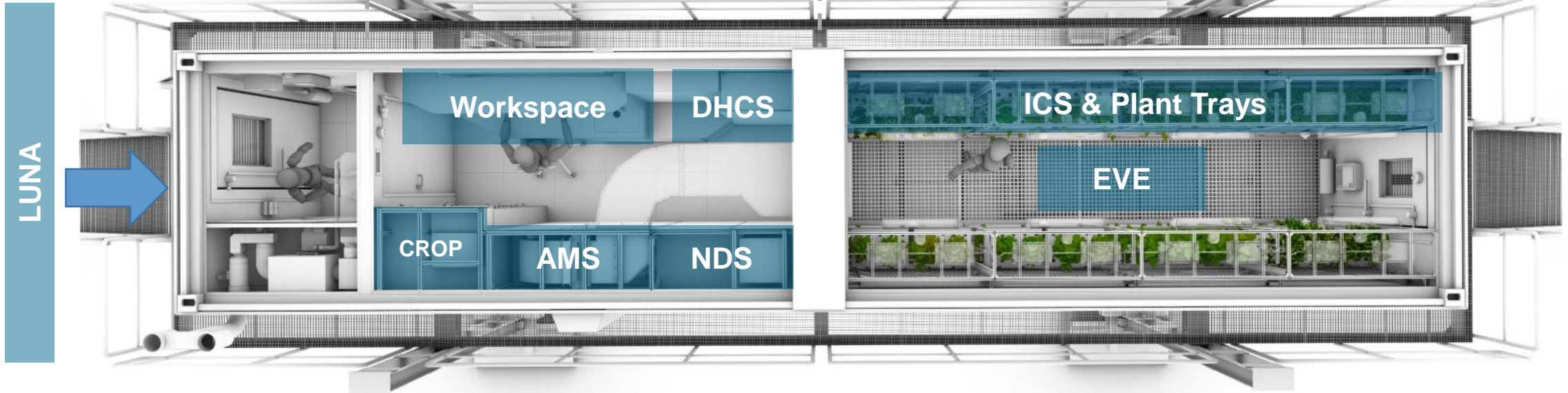
Mobile Test Facility



Cold Porch

Service Section (SES)

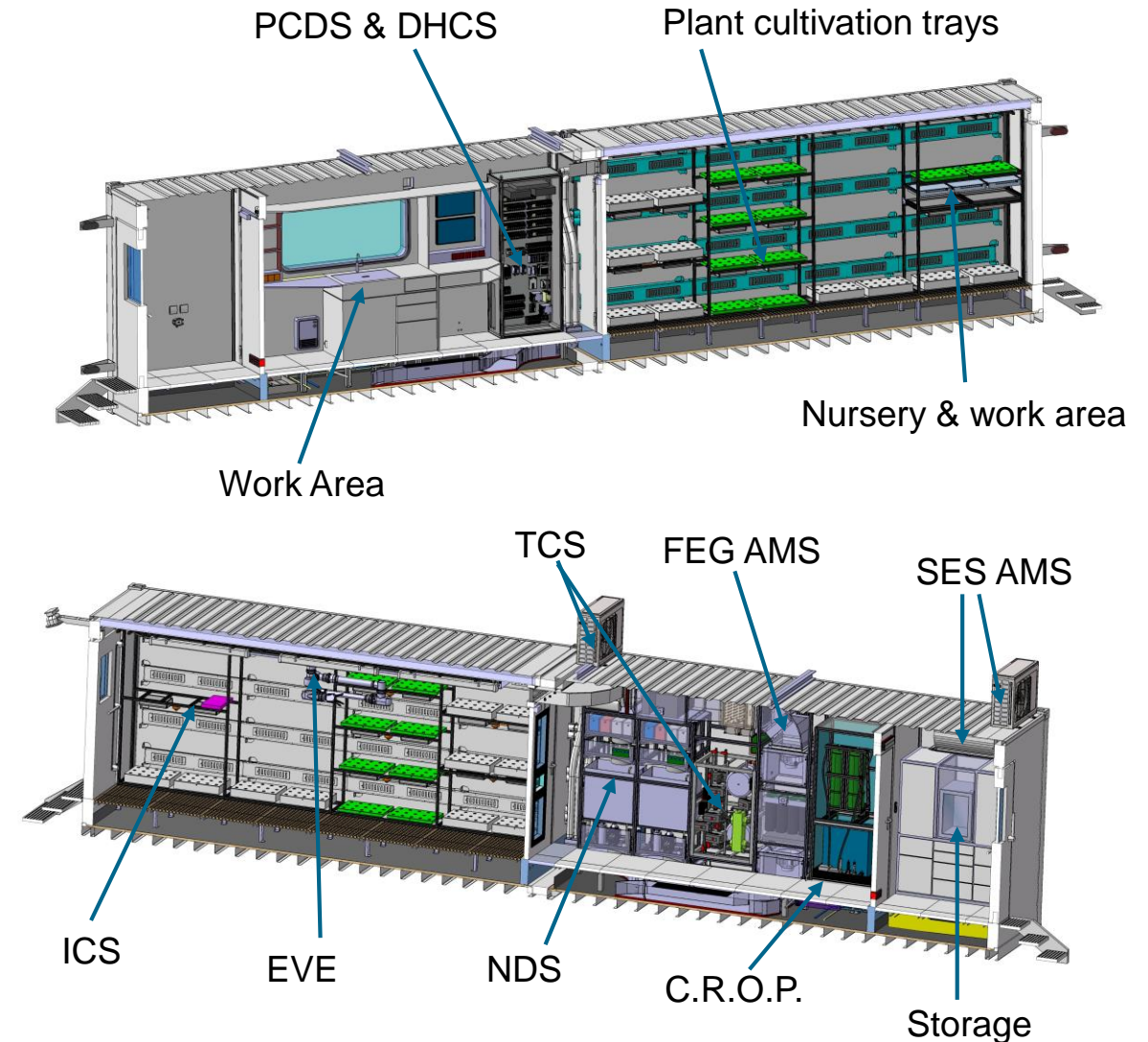
Future Exploration Greenhouse (FEG)



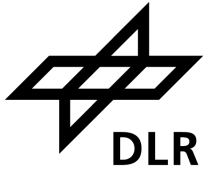
Subsystems

Controlled Environment Agriculture (CEA)

- Simplified Structure & Mechanisms
 - Merging containers to facilitate transport and installation
- Upgraded Atmosphere Management System
 - New sensors to monitor particulate matter, VOCs and ethylene
 - CO2 scrubber to remove excess CO2
 - New dehumidifier & condensate water recovery system
 - New Service Section air conditioning unit
- New Thermal Control System
 - Avoiding leakages
- New PCDS & DHCS designs
- Modified Nutrient Delivery System
 - More robust high pressure pumps
 - Simplified piping architecture
 - Integrated heating elements for cleaning mode
- New work areas & storage cabinet



Progress

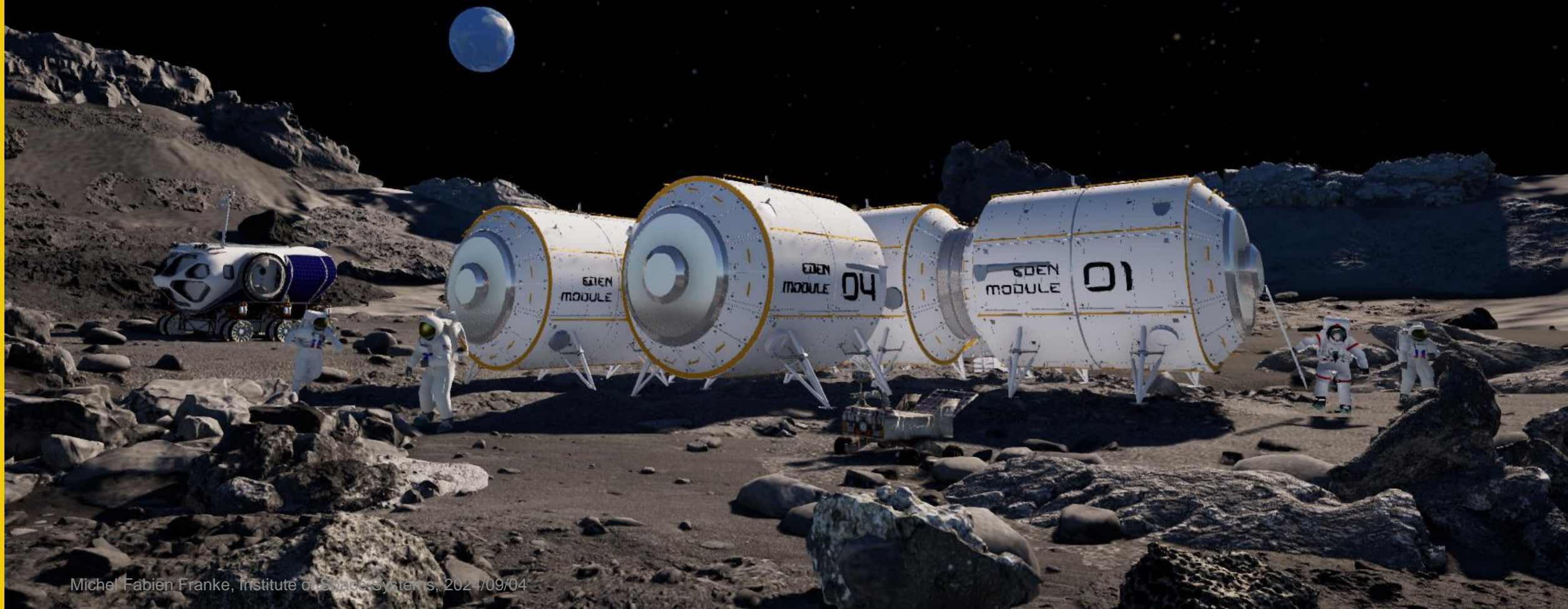


EDEN LUNA

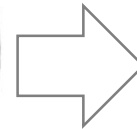
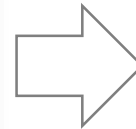
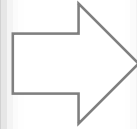


Michel Fabien Franke, Institute of Space Systems, 2024/09/04

LAM-GTD



Project



Laboratory Testing

- CEA breadboard
- Laboratory environment

Analogue Testing

- Integrated system, but COTS parts
- Extreme environment

Ground Test Demonstrator

- Space-ready system
- Space-like environment

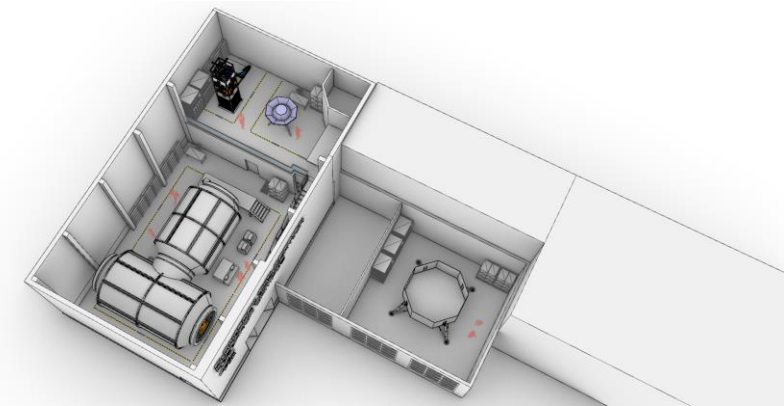
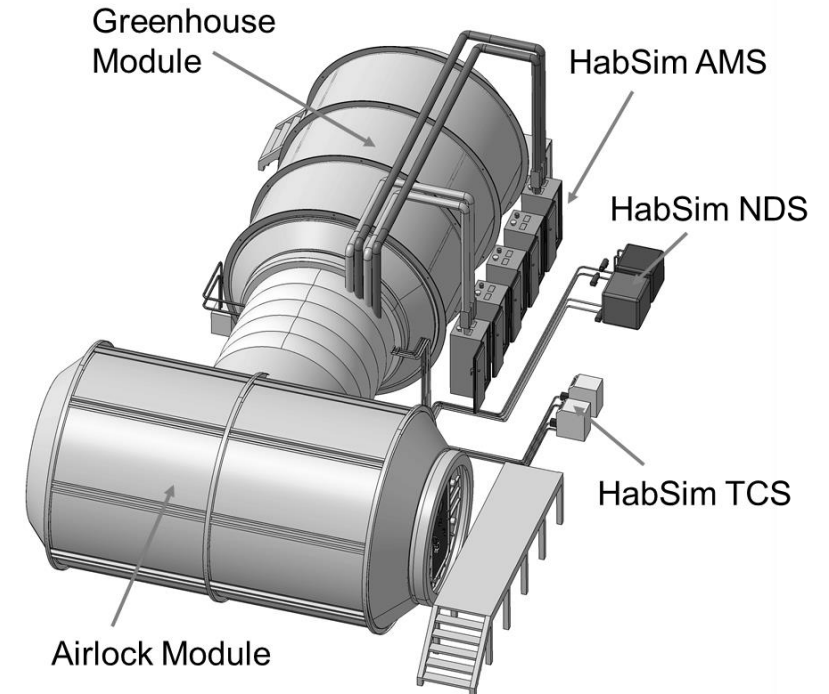
Lunar Agriculture Module

- Full space system
- Lunar environment

- *LAM*: Space grade BLSS to cultivate plants for lunar surface exploration missions
- *GTD*: Full-size mockup of the LAM with minor adaptations to terrestrial conditions
- *Goal*: Increasing the TRL & obtaining more accurate mass flow data

Key Elements

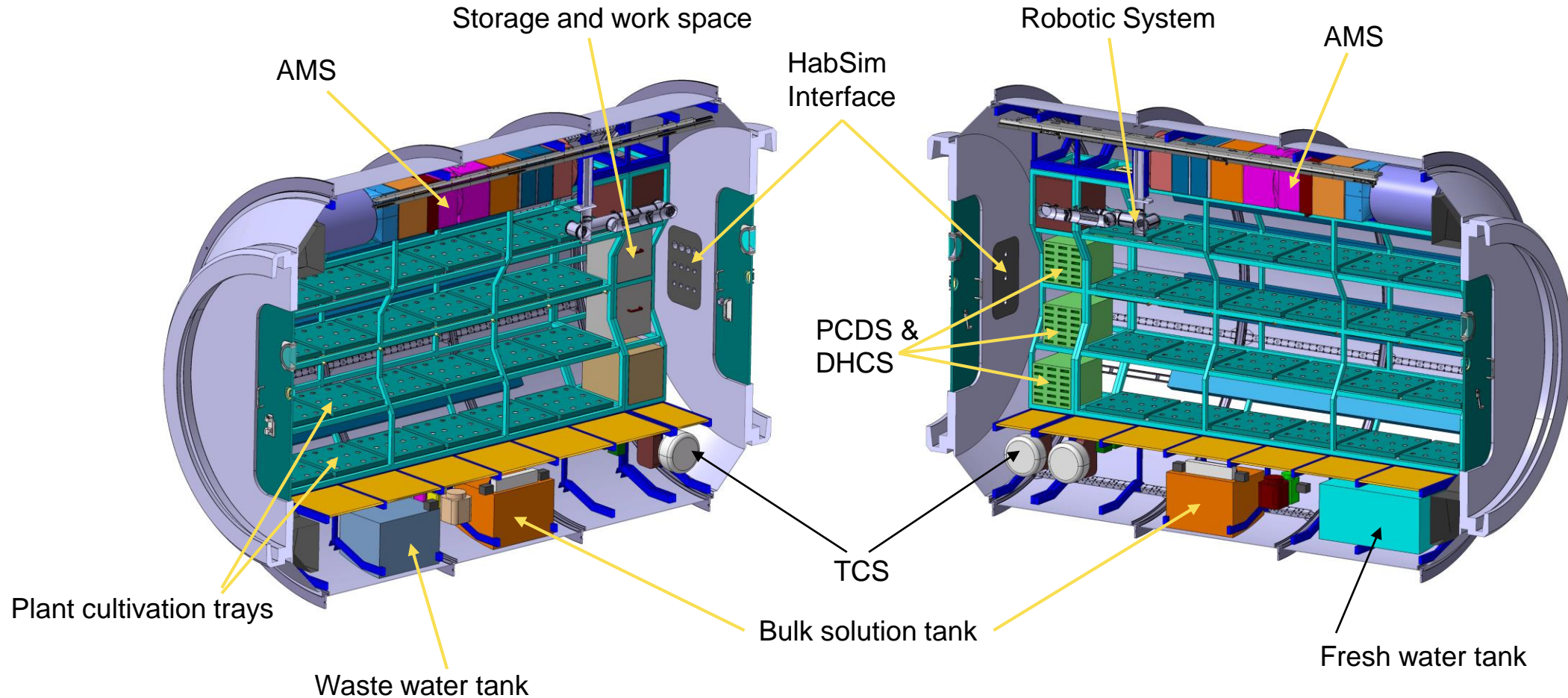
- Airlock Module for safe crew in- and egress
 - Ability to operate at reduced pressure (57 kPa)
- Habitat Simulator to determine gas & resource exchange
 - Realistic mass flows (greenhouse/habitat)
 - Complete input/output considerations
- Secondary payload platform
 - C.R.O.P.® bio-filter for urine processing
 - Algae reactors
 - Insects
- Enhanced robotic system
- Greenhouse module
 - 23.5 m² cultivation area
 - 48 Plant cultivation trays



System



LAM-GTD



Progress



Linked **in**



Thank you!

Topic: **From Antarctica to the Moon**
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Date: 2024-09-04

Author: Michel Fabien Franke et al.

Institute: Institute of Space Systems

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