

EDEN NEXT GENERATION

**GROUND-BASED DEMONSTRATOR FOR THE FIRST SPACE-READY
LUNAR AGRICULTURAL MODULE**

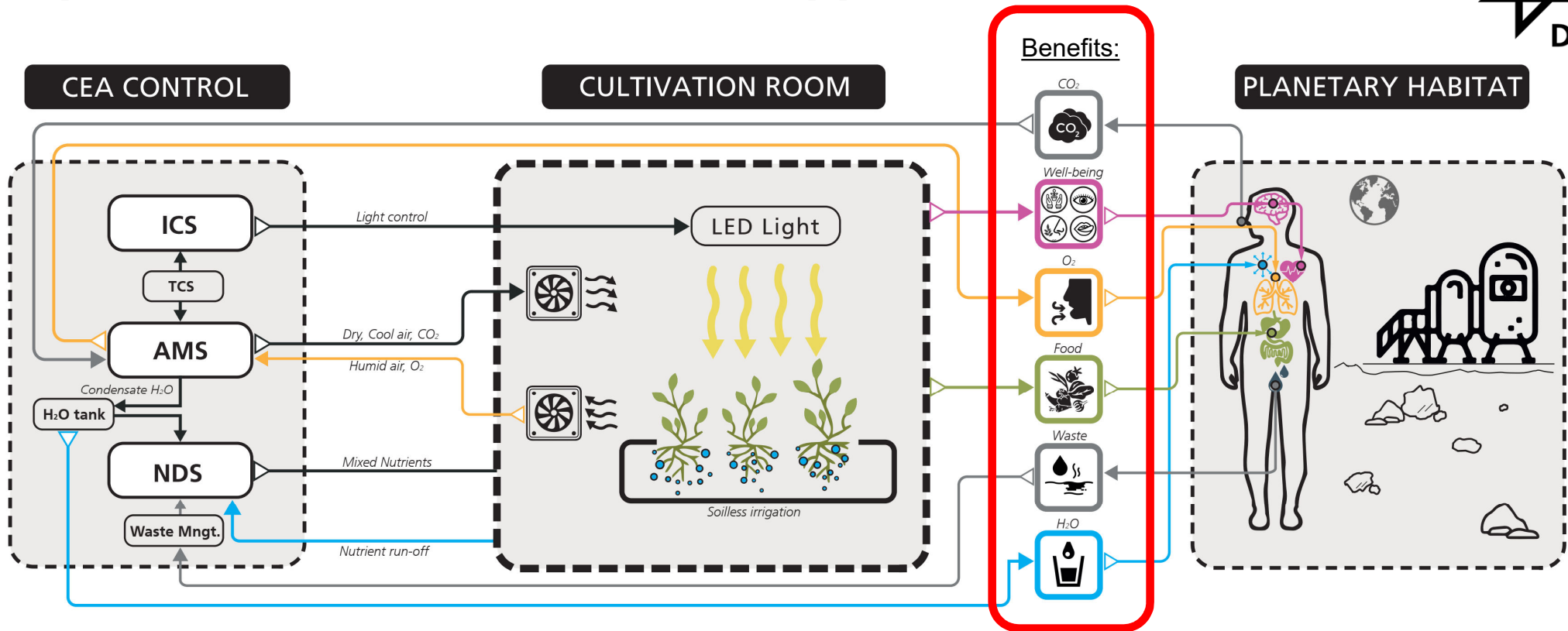
Canadian Lunar Workshop (31st of May 2023)

Dr. Daniel Schubert - Institute of Space Systems



BACKGROUND

Space Greenhouse: All-in-One Approach



- Controlled Environment Agriculture (CEA) Technologies
- Fresh food, CO₂ fixation, O₂ generation, water recycling, waste mgmt., well-being
- Necessity to fully integrate CEA technologies into one lightweight space system!

NDS: Nutrient Delivery System **AMS:** Atmosphere Management System **ICS:** Illumination Control System



Main Analogue Mission 2018
(+Delta Missions 2019/2020)



NASA/DLR Joint Analogue
Mission 2021



- Plant Cultivation Technologies for Space
- Five years of analogue testing at the German Research Station Neumayer III in Antarctica
- Stepping Stone towards long-duration & permanent Human Outposts on Moon/Mars

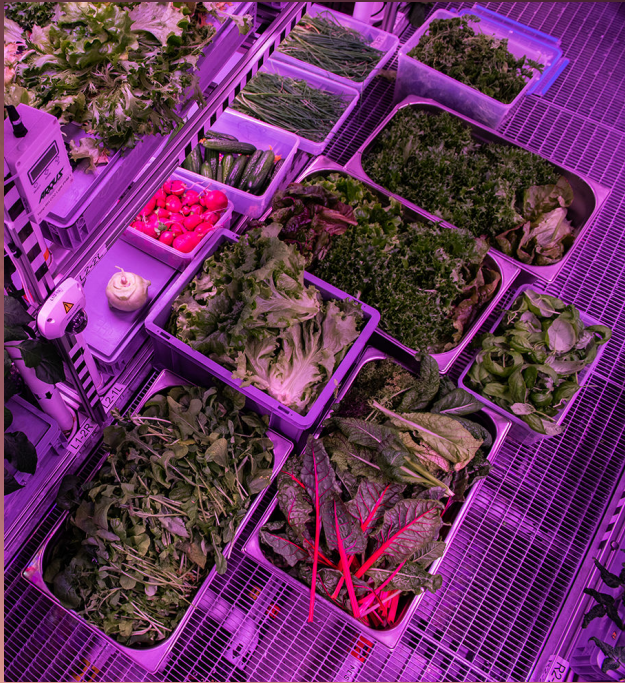


EDEN ISS



- Test of critical cultivation technologies in extreme environment
- Humans-in-the-loop investigations, microbial investigations, crop selection, etc.
- Controlled by Mission Control Center (MCC) in DLR Bremen
- Significant public outreach and spin-off projects

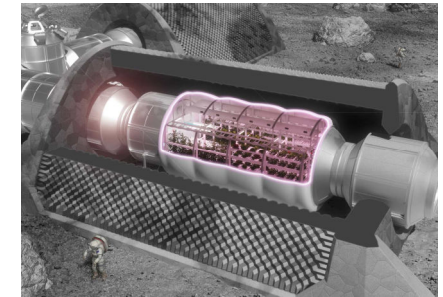
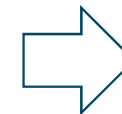
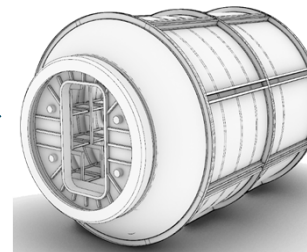
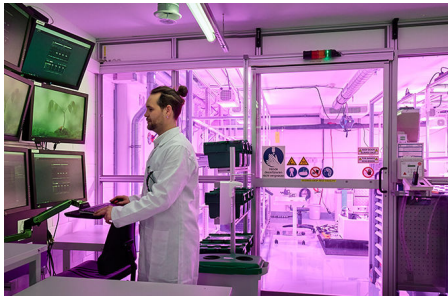






LUNAR AGRICULTURAL MODULE

Development Pathway



Laboratory Testing

- CEA breadboards
- Functional principles

Analogue Testing

- Integrated system, but COTS parts
- Still breadboard level
- Extreme environment

Ground Testbed

- Space-ready system
- Full redundancy & S/S accommodation

Space Deployment

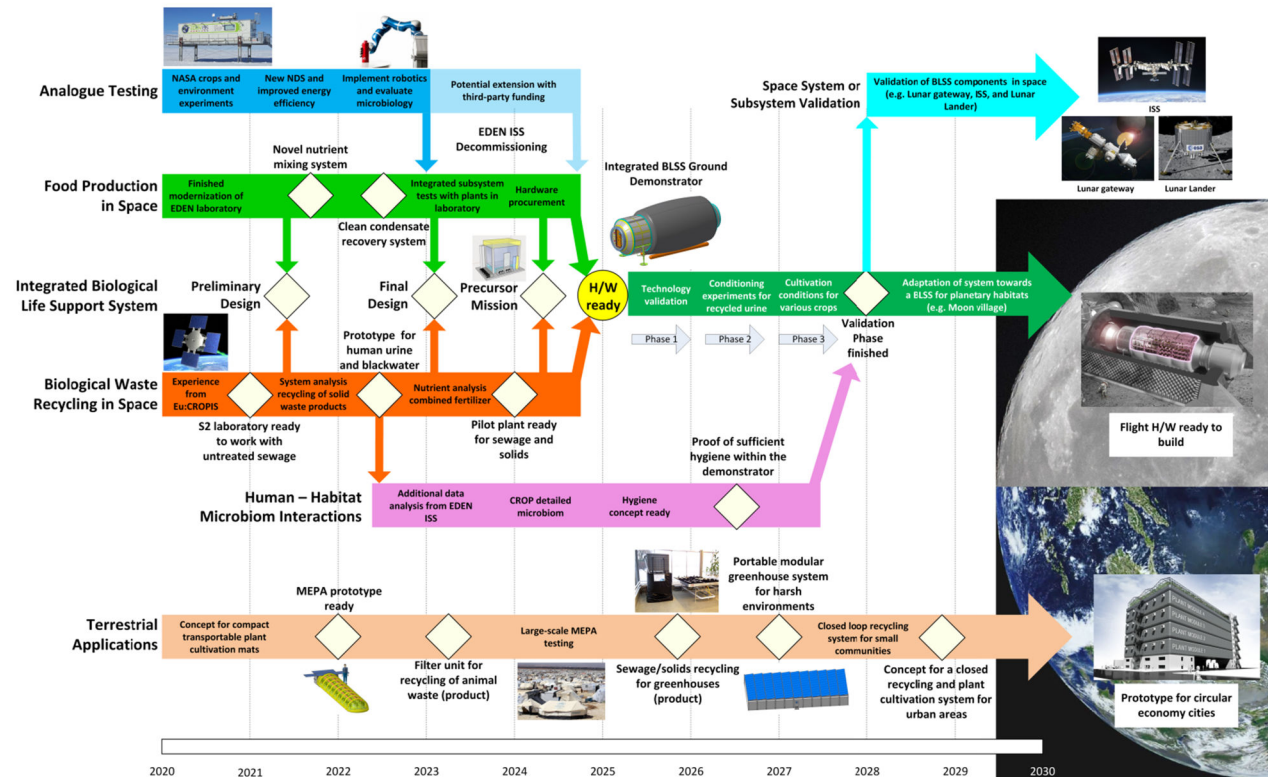
- Full space flight system
- Bio-regenerative Life Support System

- Increasing the TRL
- Final goal is a full-size life support module for human exploration purposes

DLR Roadmap (2020 – 2030)



DLR Roadmap (Released in 2020)



- In 2020: DLR Roadmap for the development of *Bio-regenerative Life Support Systems*
- R&D of a Ground Test Demonstrator (GTD) by ~2026
- 2030: Space-ready design of an integrated greenhouse system for Lunar surface
- Transition to industry for hardware build-up

Lunar Agricultural Module – Ground Test Demonstrator



Space Design & Science

- All subsystems fully integrated
- Realistic mass flows (greenhouse/habitat)



CEA Technologies



AI-Robot System

Key Features (DLR Institutes)

- Controlled Environment Agriculture (CEA) integration
- AI - robotic assistance
- Urine processing => water recovery
- Risk mitigation applications



C.R.O.P. Urine Filters



Risk Mitigation

International Partnerships



Canadian Space Agency

- Official Lol signature of CSA at IAC in Paris 2022
- Long-term partnership within DLR's roadmap
- Subsystem contribution by CSA for Ground Test Demonstrator (GTD)

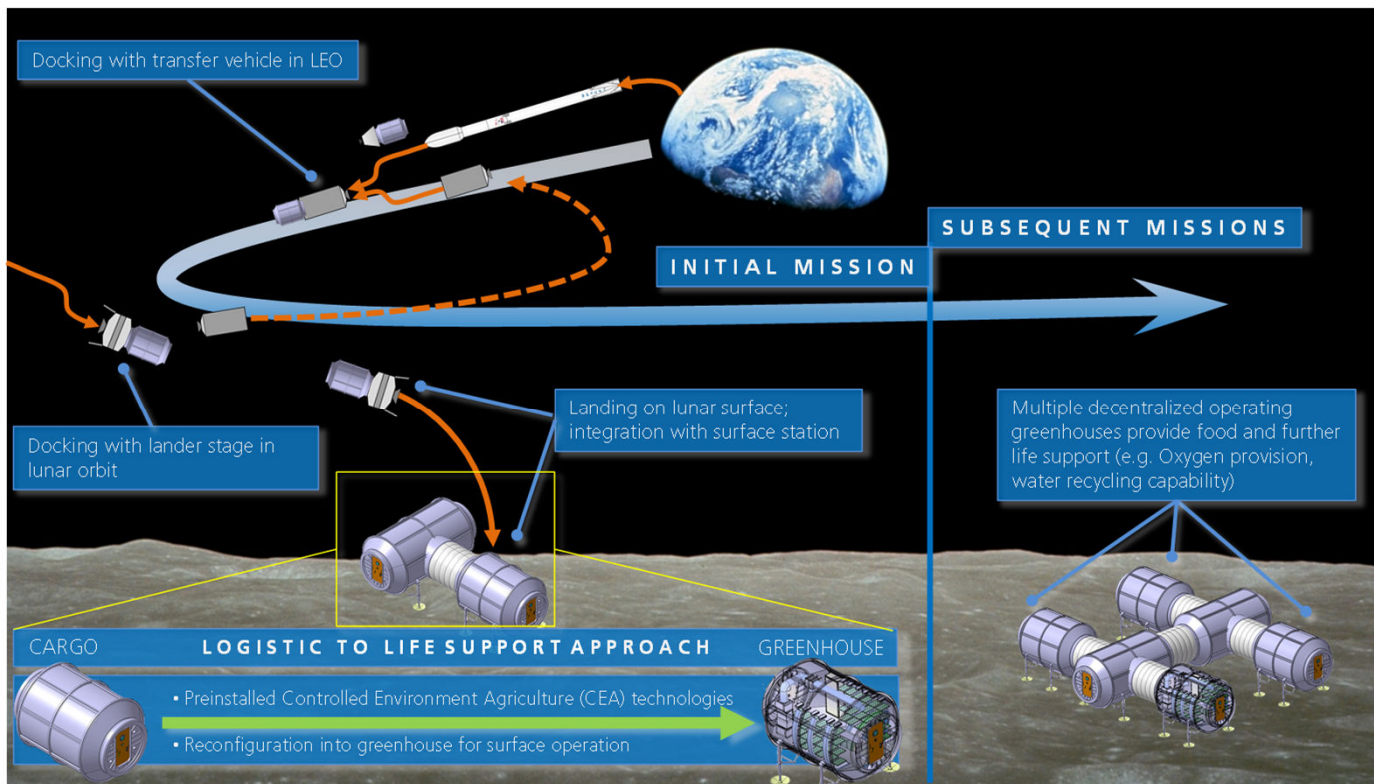
Other Partnerships

- Other international partnerships (e.g. NASA, ASI) in the early stage
- Industry involvements as well (Airbus, TASI)



Official signature of between CSA and DLR during IAC 2022 (left to right: Lisa Campbell (CSA), Anke Kaysser-Pyzalla (DLR), and Anke Pagels-Kerp (DLR)).

Logistic-to-Life Support Approach



Mission scenario for the Logistic-to-Life Support Approach



Food



Oxygen



Water



Initial Mission: Cargo delivery to Moon

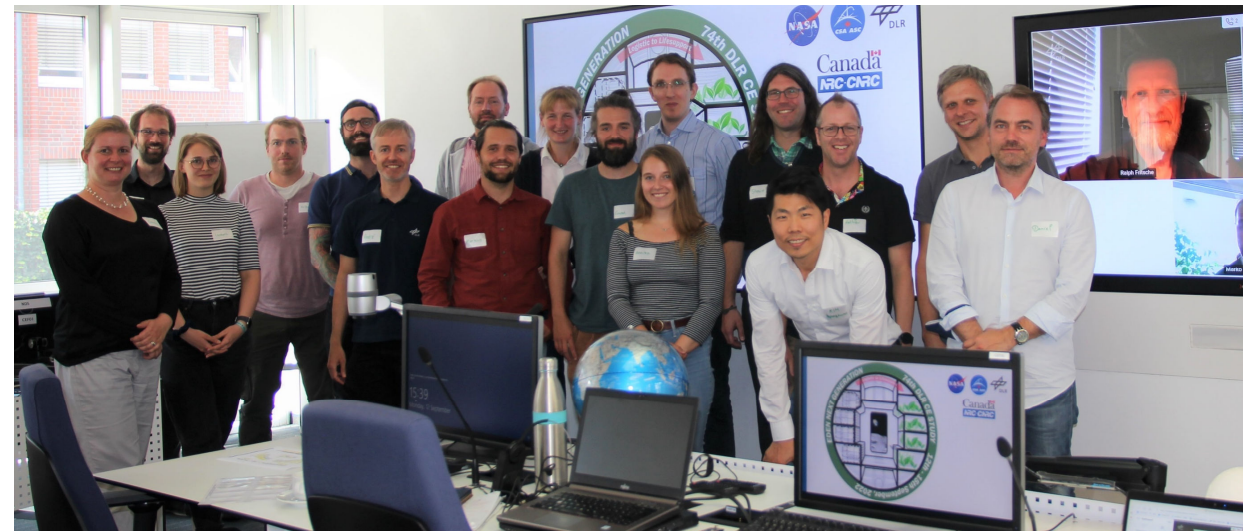
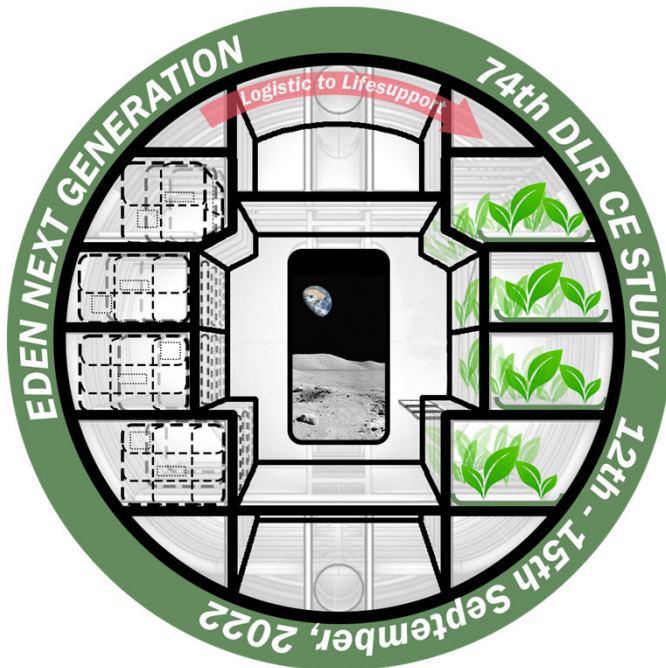
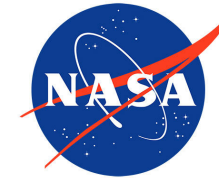
Current estimate: 6.400 kg cargo payload



Second Mission: Life Support Module

**Biomass: ~ 1 -1,5 kg/ d edible biomass;
Oxygen/ H2O recovery**

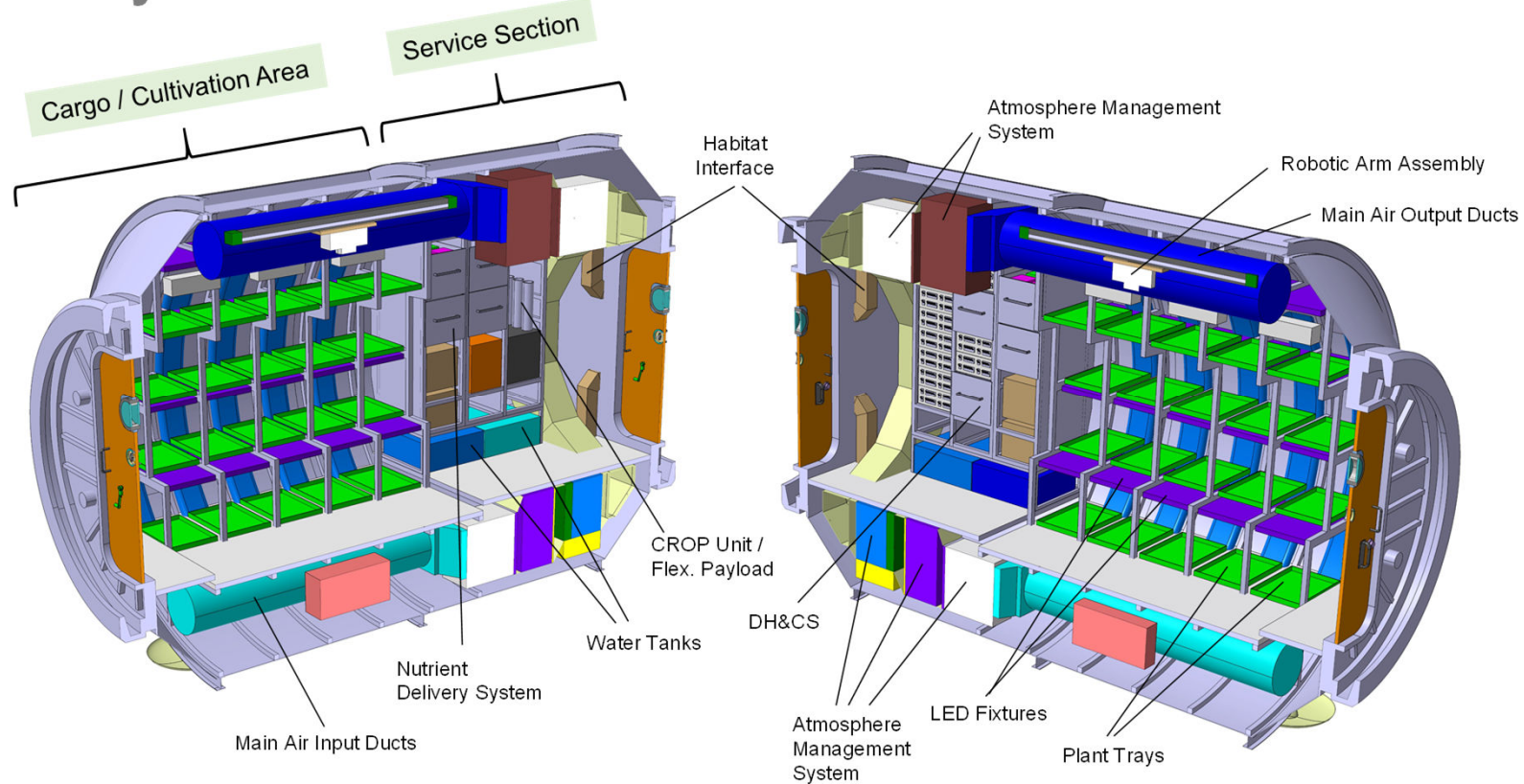
Concurrent Engineering Study



Concurrent Engineering Team at DLR Bremen (Sep. 2022)

- First combined design study with all partners (Sep. 2022)
- Outcome: Full pre-design, subsystem accommodation
- CSA & NRC as full partner; NASA as participating observer

Internal Layout of Ground Test Demonstrator

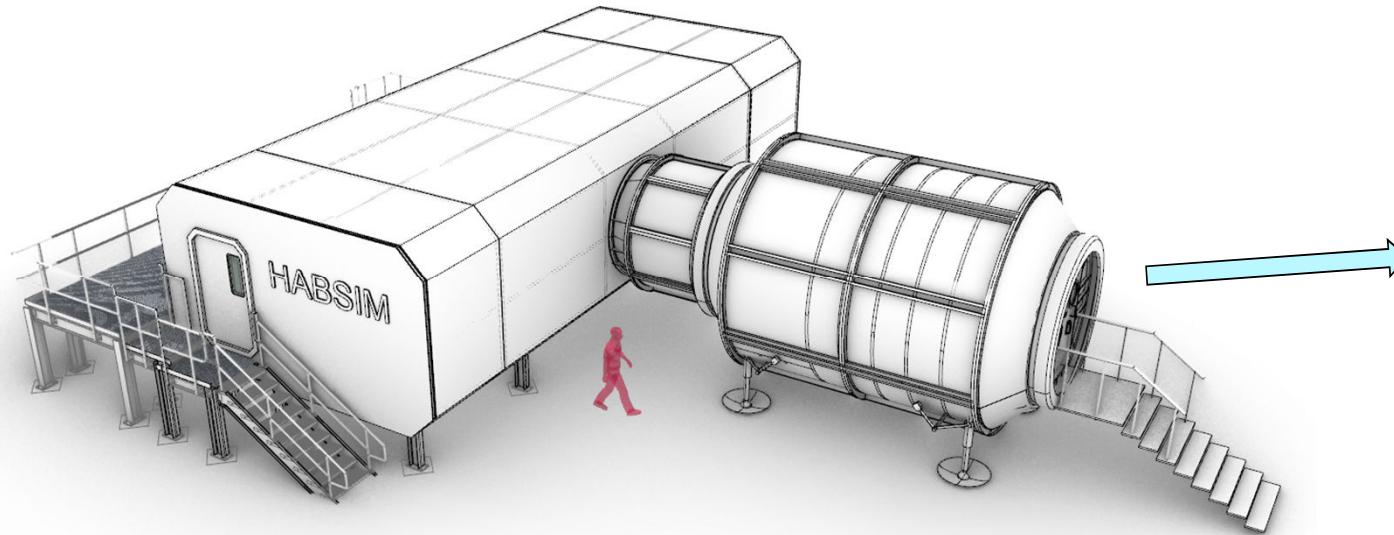


- Space-ready design & Realistic mass flows (greenhouse/habitat)
- Real testbed towards first Lunar Agriculture Module
- Service Section: All CEA technologies; Cargo section => Cultivation area (~16 m²)
- Integration of secondary payload rack (e.g. waste management system or algae reactor)

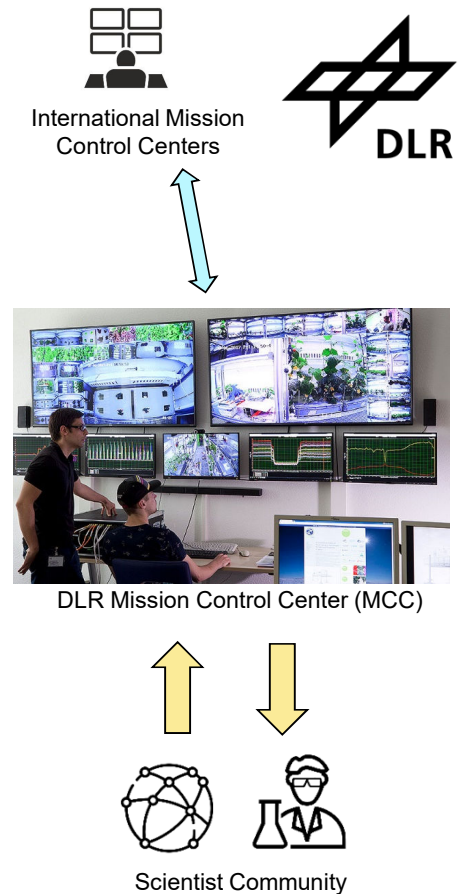


GROUND TEST DEMONSTRATOR

Ground Test Demonstrator (GTD)

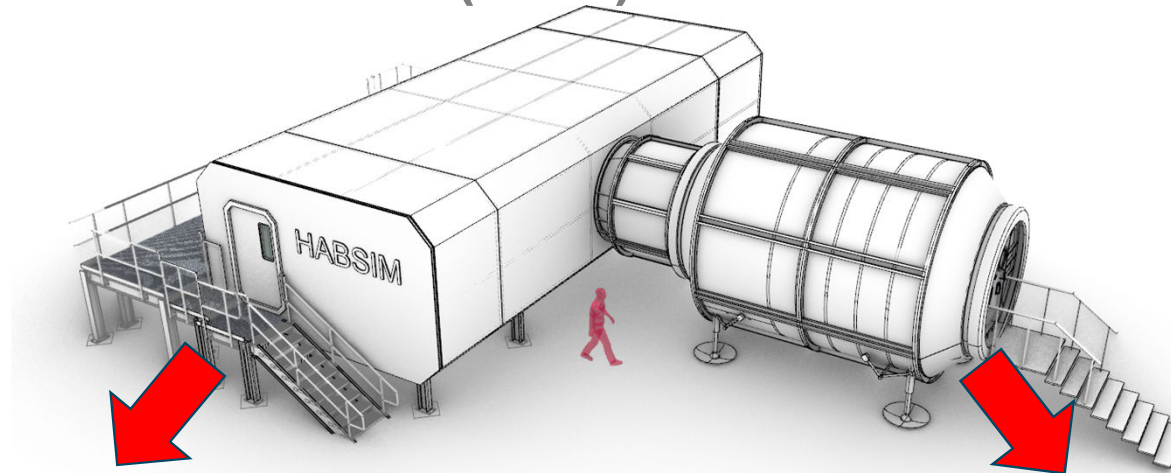


Preliminary design of the ground test demonstration unit



- 2 Elements: Greenhouse Test Demonstrator (GTD) and the Habitat Simulator
- Realistic thermal, power, data, and consumables provision
- Integrated testing of CEA techs & humans-in-the-loop (procedures)
- Long-duration testing of food production

Ground Test Demonstrator (GTD)



Habitat Simulator:

- Integrated laboratory (Sample & consumables storage)
- Food Processing Facility => ("Space Kitchen")
- Food storage technologies
- Waste management interfaces

Cargo/Greenhouse Module:

- Production of edible crops
- *Pick & Eat* cultivars, but also other crop types



Extended food storability



Space Kitchen

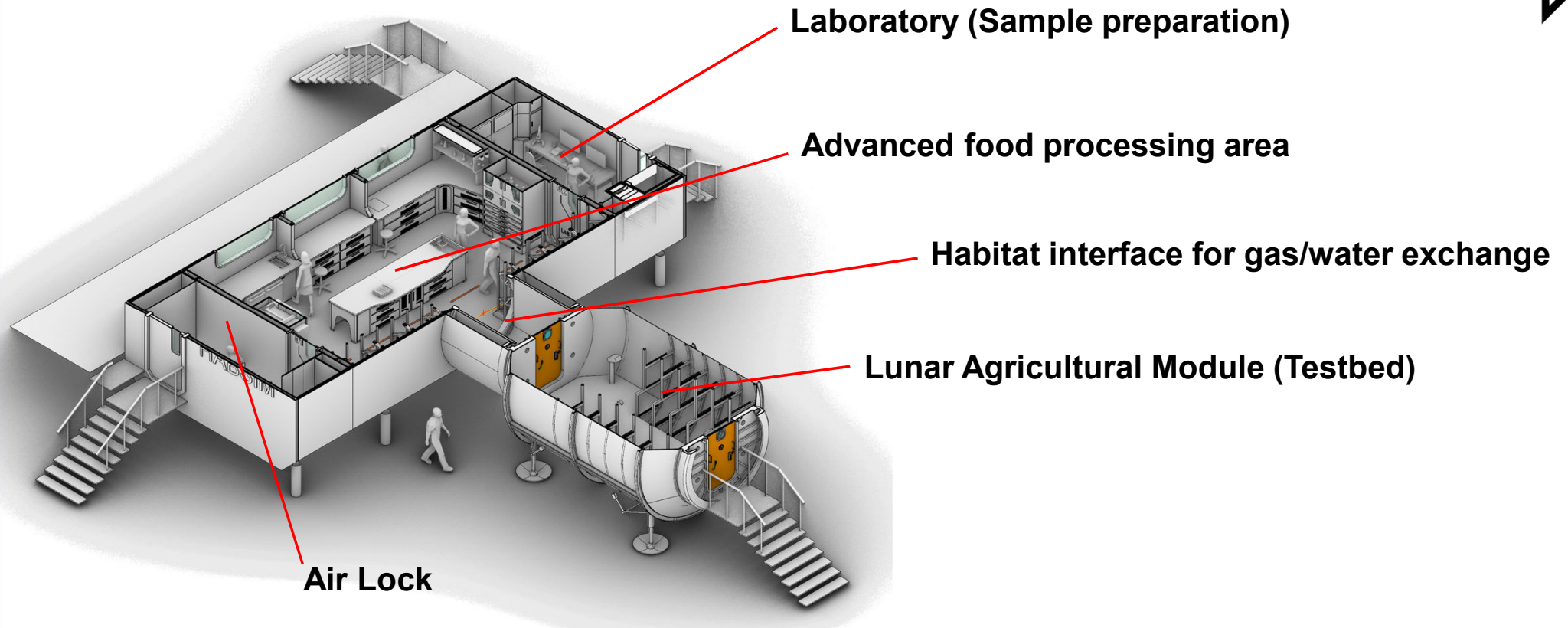


Other food technologies

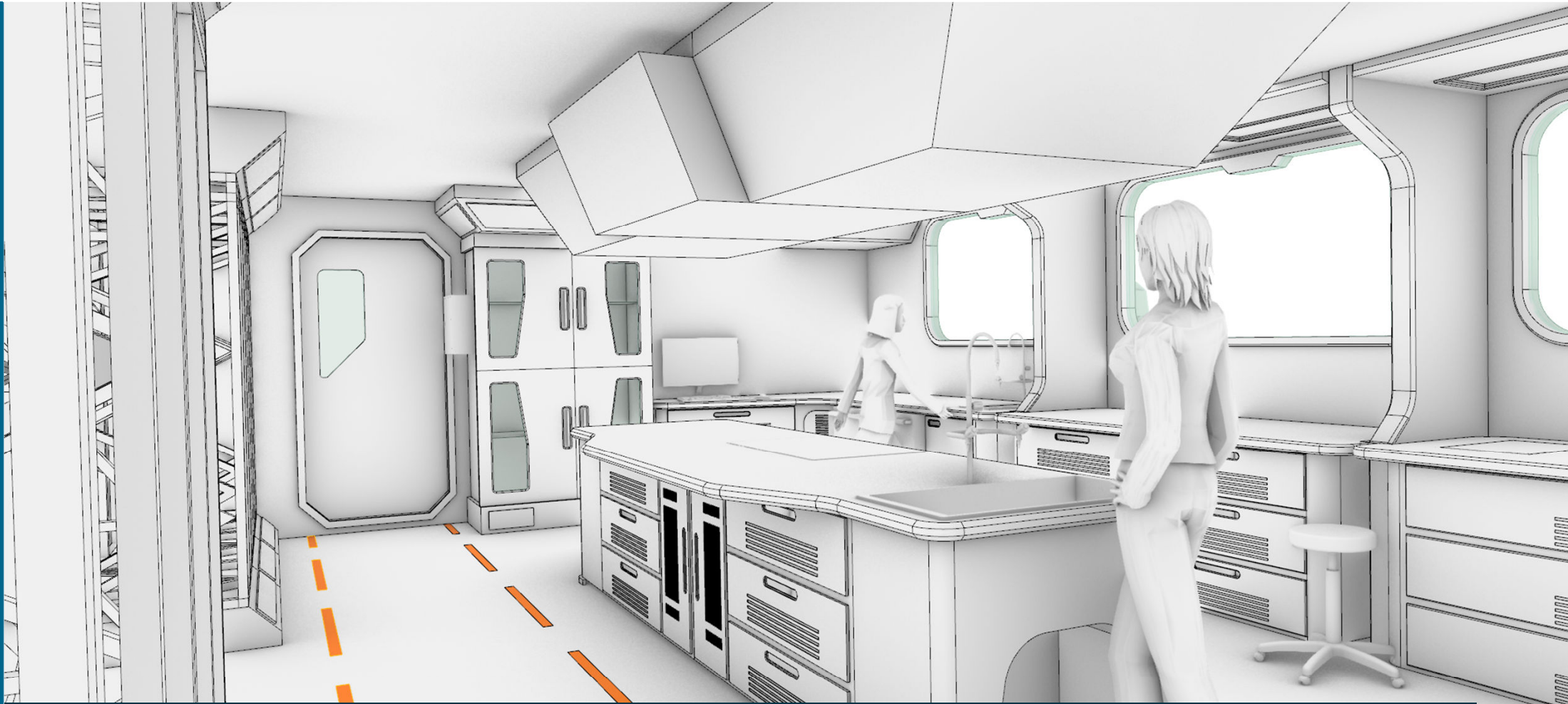


Main greenhouse system

Ground Test Demonstrator (GTD)

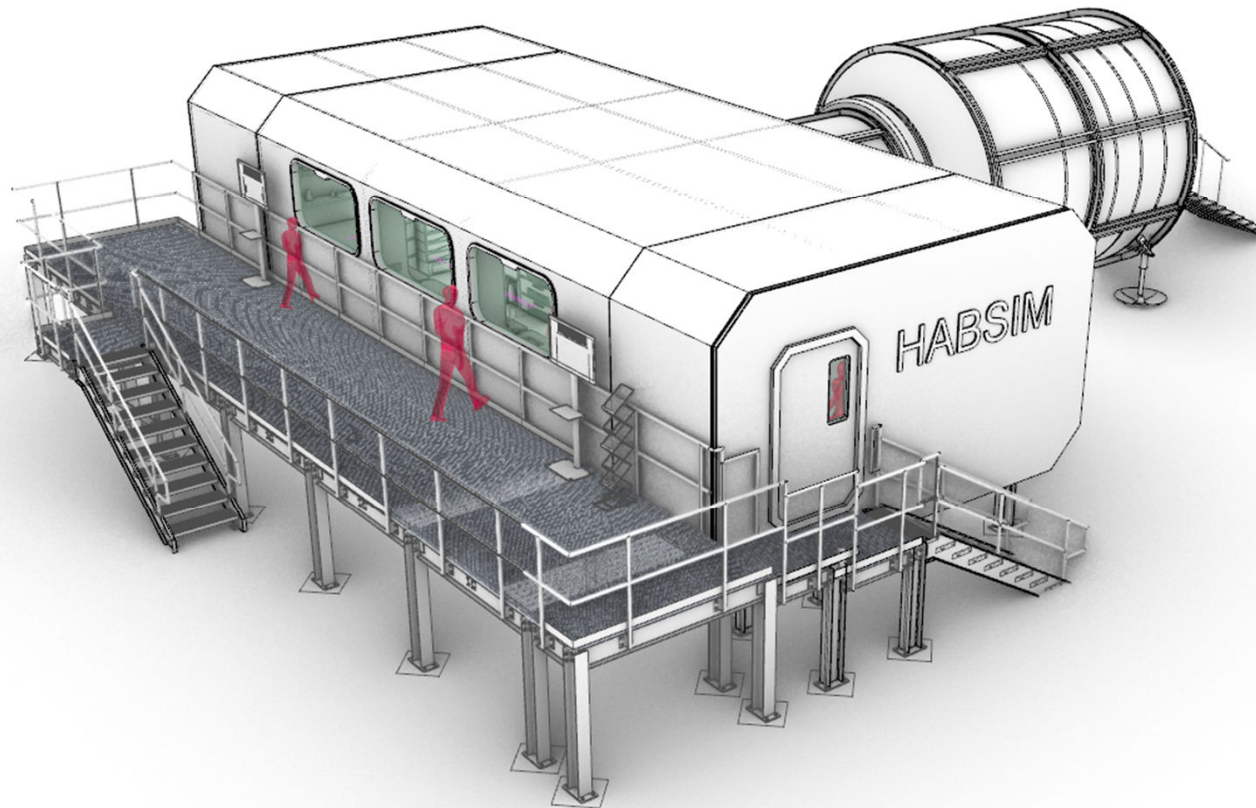


- SEED-to-MEAL Approach
- Holistic combination of all food related systems into one research facility
- Open to the community for implementing new food systems



- Flexible research racks for additional food systems => (insect, algae, artificial meat)
- Modified atmosphere food storage systems
- Smart cooking/ preparation systems (e.g. 3d-food printing)

Public Engagement



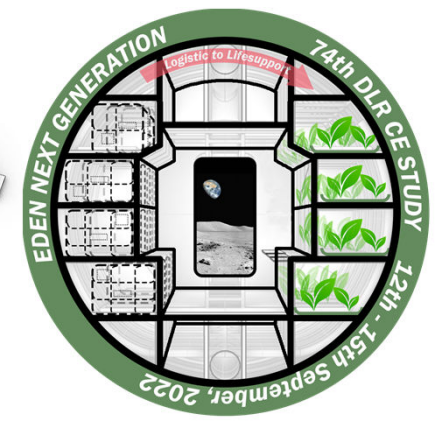
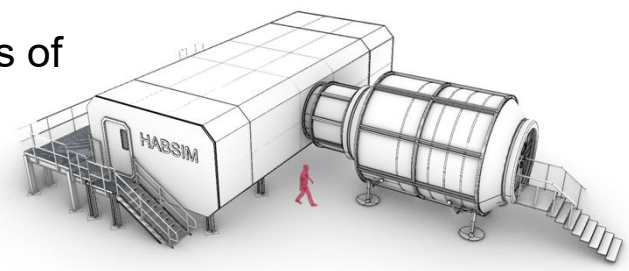
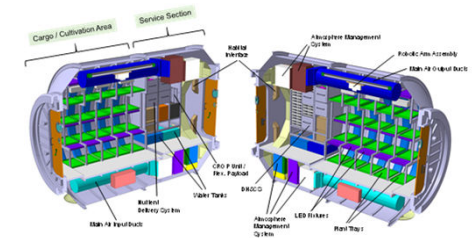
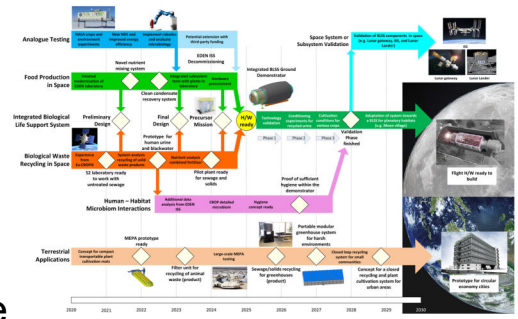
- Dedicated observation deck (with three main windows)
- Visiting groups have direct view into laboratory
- Sustainable food preparation and potential for technology transfer



SUMMARY & CONCLUSION

Summary & Conclusion

- DLR roadmap for BLSS => Long-term R&D program (2020-2030)
- First and fully integrated test greenhouse module for the Lunar surface (logistic-to-life support approach)
- Ground Test Demonstrator (GTD) will test all aspects of food production (seed-to-meal)
- Strategic partnership with Canadian Space Agency
- Open for international collaboration!



Thank you for your Attention!

Impressum



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Date: 31st May 2023

Autor: Dr. Daniel Schubert

Institute: Institute of Space Systems

Image credits: DLR, ESA, BMBF, AWI, ...