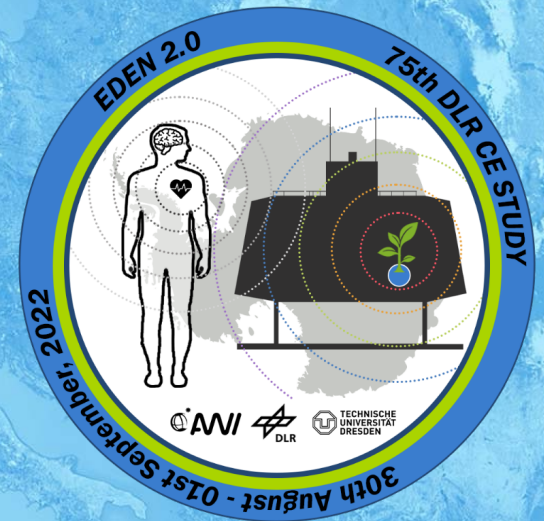


# EDEN 2.0 GREENHOUSE DESIGN STUDY FOR NEUMAYER STATION III IN ANTARCTICA



Kyunghwan KIM, Dr. Daniel Schubert, Vincent Vrakking, Jess M. Bunchek



# EDEN ISS



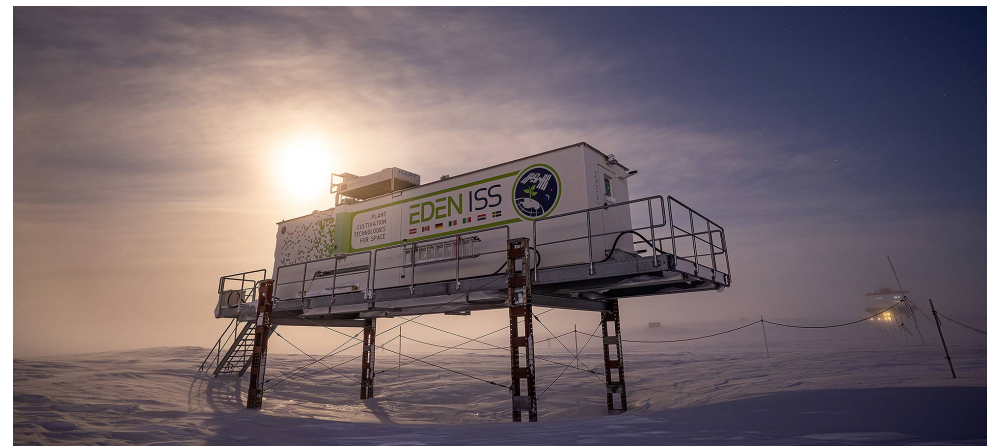


## 02.1. EDEN ISS

Steppingstone towards long-duration & permanent Human Outposts on Moon/Mars



- H2020 Project (~5M€)
- 14 partners from industry, universities, research institutes
- 8 countries
- Start: 2018 End: 2022
- First complex plant cultivation at German Neumayer Station III (AWI) in Antarctica





NASA/DLR Joint Mission  
2021



Main Mission 2018  
(+Delta Missions 2019/2020)





# EDEN 2.0



# OBJECTIVE



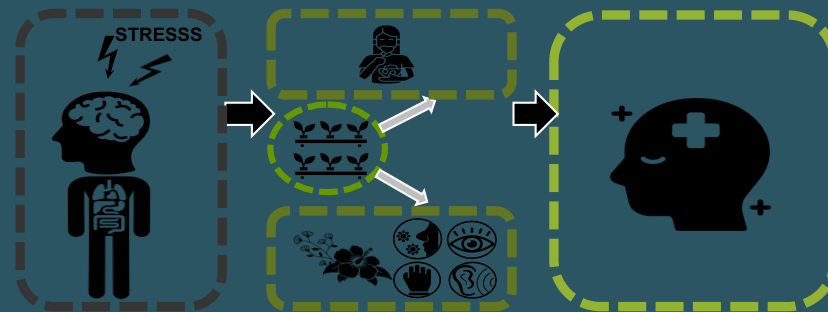
This study concentrates on the development of a **testbed** to evaluate **human-plant interactions** aimed at **enhancing mental health and food production** in extreme environments.



EDEN-ISS



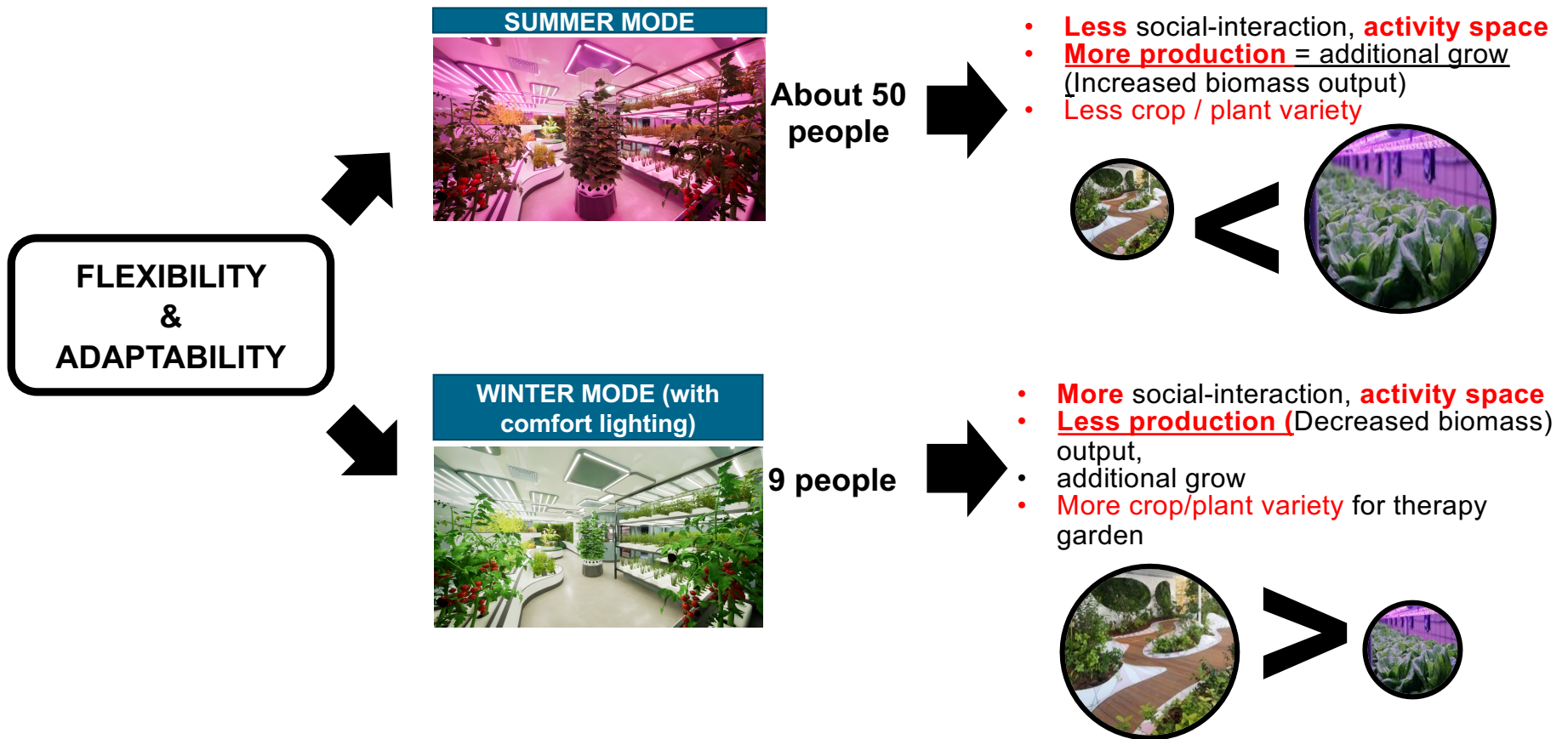
NEUMAYER STATION III



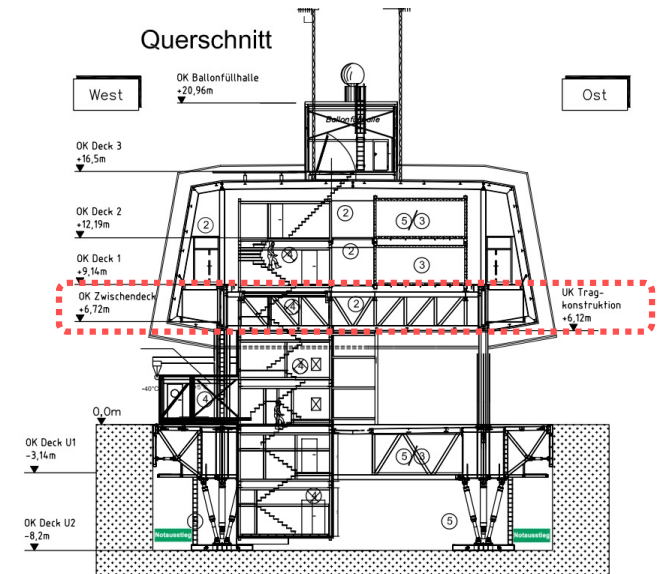
Countermeasure (CM)  
strategies with green space



# 2 MODES: PRODUCTION & SOCIAL AREA

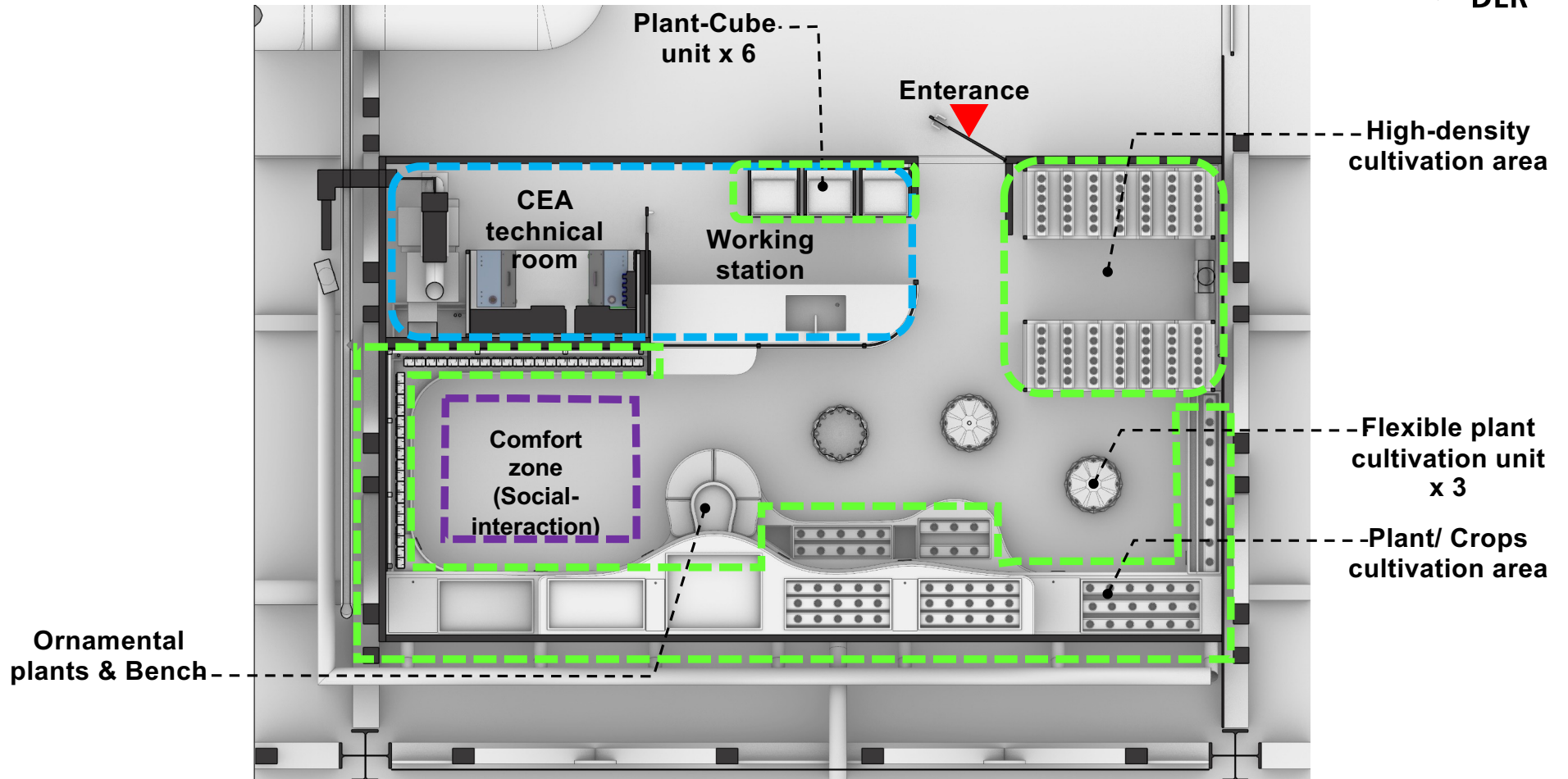


# EDEN2.0 IMPLEMENTATION ROOM





# PLAN



# DIFFERENT MODES OF EDEN 2.0



SUMMER MODE



WINTER MODE (with comfort lighting)





# INTERNAL CONFIGURATION



ENTRANCE, SERVICE SECTION, HIGH-DENSITY CULTIVATION AREA



# WORKING STATION VIEWS



SERVICE SECTION: WORKING STATION



SERVICE SECTION:  
CEA TECHNICAL ROOM ENTRANCE





# INTERNAL CONFIGURATION



SOCIAL-INTERACTION AREA



LIGHT MODE -1  
(Plant cultivation)

SOCIAL-INTERACTION AREA



LIGHT MODE-2  
(Comfort lighting)

# COMFORT ZONE(Social-interaction) VIEW-3



SOCIAL-INTERACTION AREA,  
FLEXIBLE CROP CULTIVATION AREA, HERBE ZONE



LIGHT MODE -1  
(Plant cultivation)

SOCIAL-INTERACTION AREA,  
FLEXIBLE CROP CULTIVATION AREA, HERBE ZONE



LIGHT MODE-2  
(Comfort lighting)



# FUTURE PLAN



- ❑ Further development will be conducted with the AWI team for...
  - **Lighting system** shall be defined at the next step for cultivation and security lighting type
  - **Material** and **thermal insulation** plan would be required in the further study
  - **Maintenance hatches** for structure and for all sub-systems should be confirmed
  - **Thermal bridge management plan** should be discussed for the existing structure I-beam and other possible area
  - **Fire detection system and management** should be defined for further study
- ❑ Test plan including sensors and VR/AR will be proposed in the next step

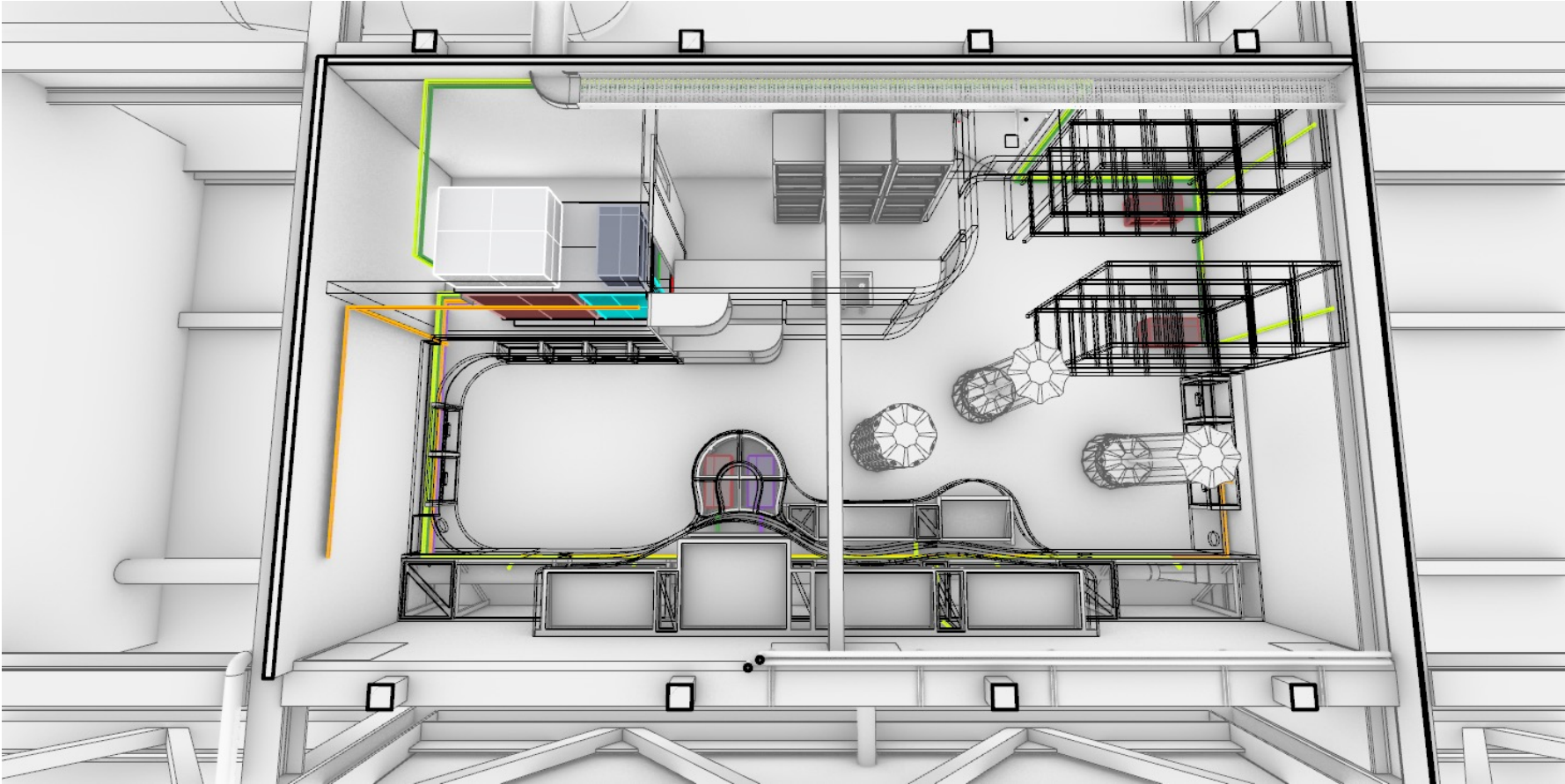
*\*AWI: Alfred Wegener Institute for Polar and Marine Research in Germany*

THANK  
YOU!

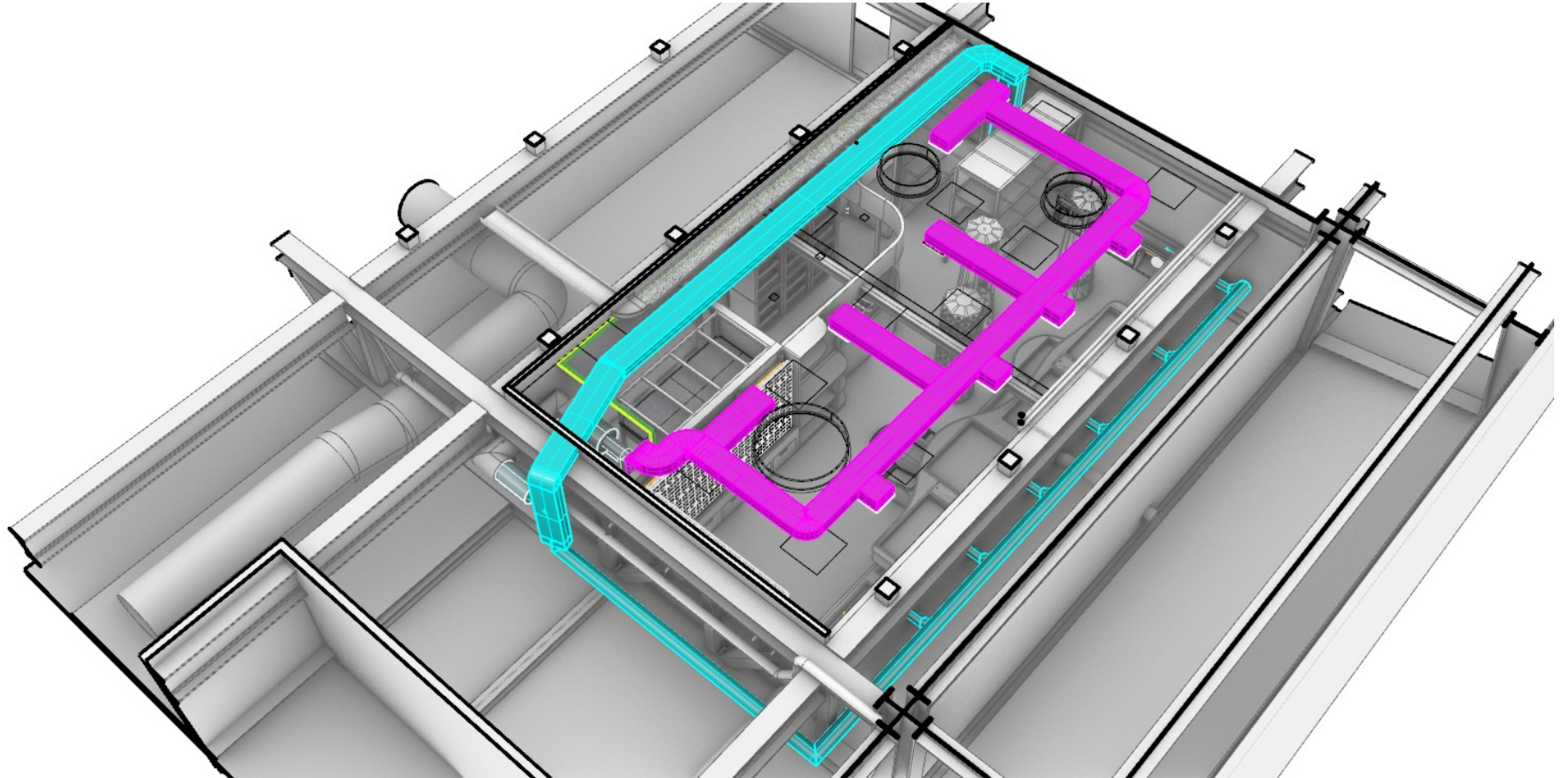




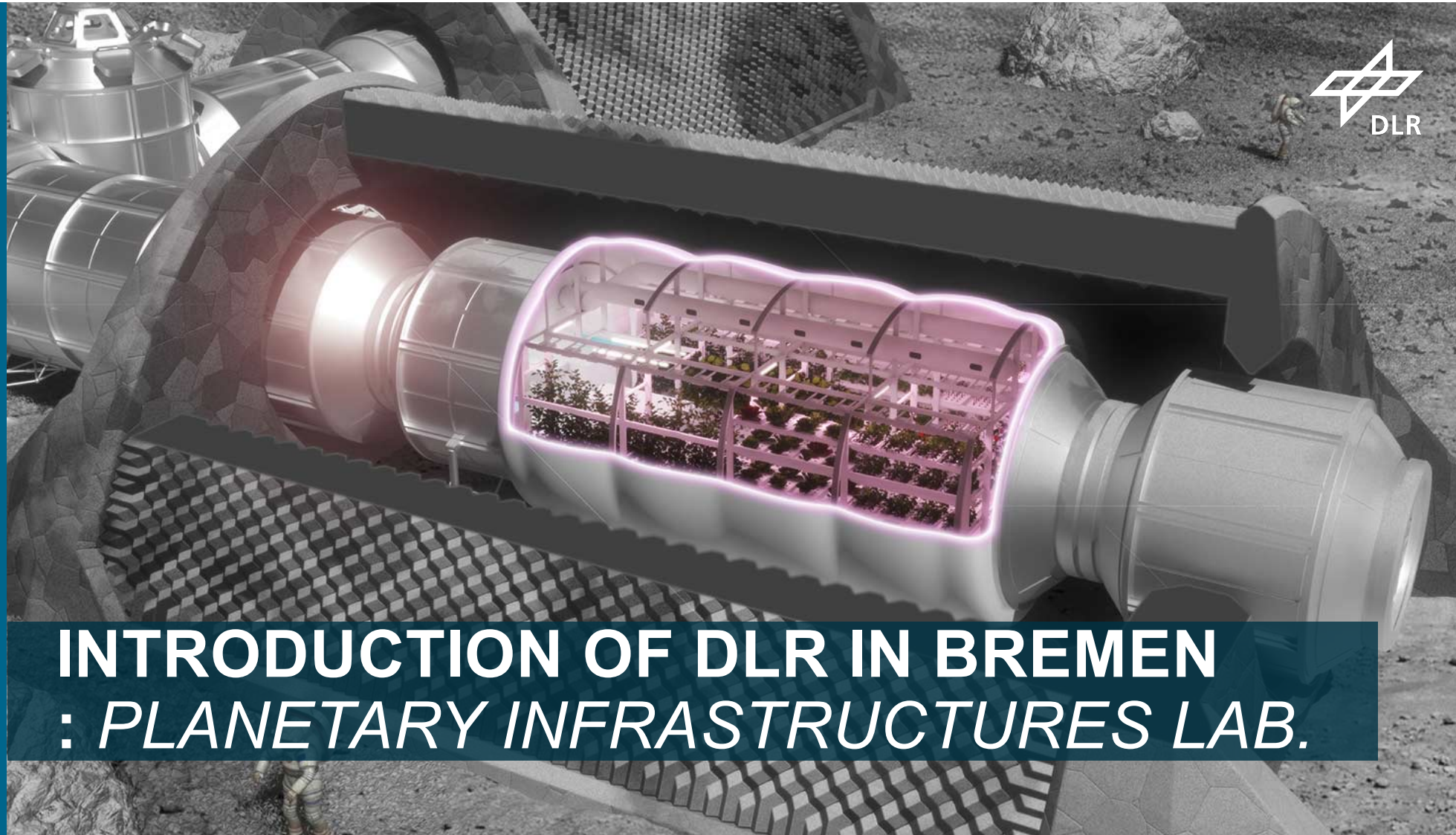
# NDS



# AMS







**INTRODUCTION OF DLR IN BREMEN  
: *PLANETARY INFRASTRUCTURES LAB.***

# Planetary Infrastructures (former EDEN Initiative)



- Research group since 2011 @ Institute of Space Systems in Bremen
- Bio-regenerative Life Support Systems (BLSS) – Greenhouse systems
- Since 2021: ISRU technology developments: Synergetic Resource Utilization S.M.U.
- Multiple R&D grants for ESA, BMBF, EU over the last 12 years
- 10+ staff members & ~10+ students
- Yearly status report



Institute of Space System (DLR)



Online: [https://www.dlr.de/irs/DesktopDefault.aspx/tabid-11286/gallery-1/gallery\\_read-Image.46.27812/](https://www.dlr.de/irs/DesktopDefault.aspx/tabid-11286/gallery-1/gallery_read-Image.46.27812/)



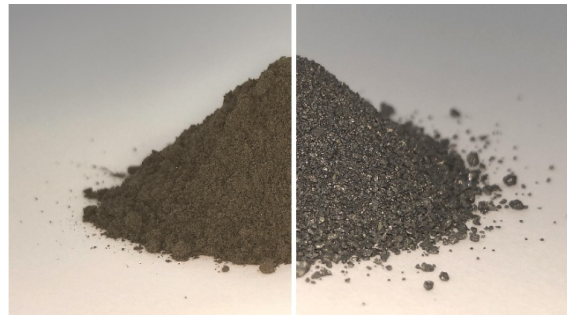
# Planetary Infrastructures – Overall Scope

## Research & Development Objectives

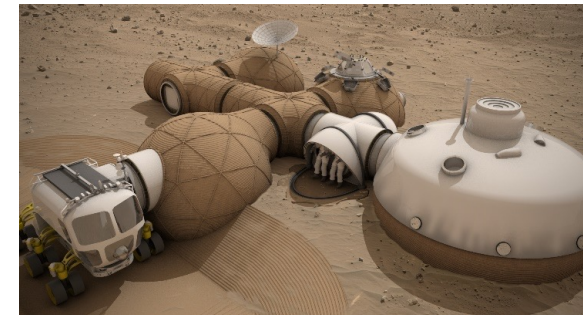
### Greenhouse Systems



### In-situ Resource Utilization



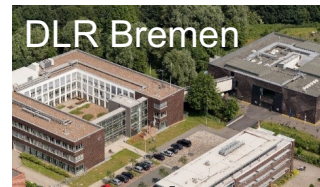
### Habitat Infrastructure Design



- Technology Hardware Developments
- System Analysis on Habitat Integrations
- Analogue Field Testing
- Technology Transfer (e.g. MEPA/ HumTech., Vertical Farming)



# Planetary Infrastructures – Laboratory Overview



**EDEN Labor**



**Mission Control Center**



**3D Printing Laboratory**



**EDEN ISS**



**ISRU Labor**



**Humanitarian Hydroponics  
Field Camp**



# RESEARCH BACKGROUND



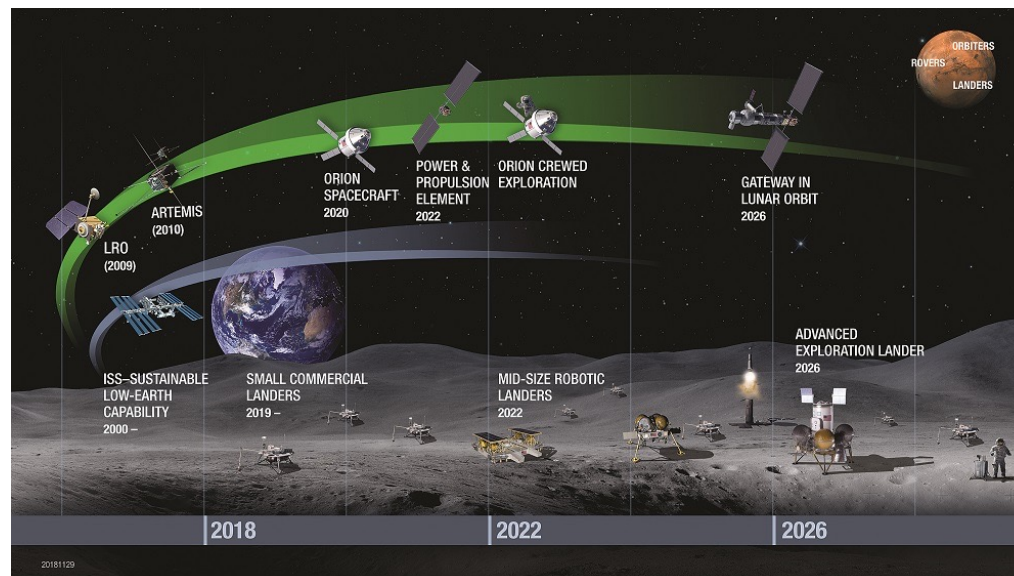


# Human Return to the Moon

- ARTEMIS Program with successful Artemis I Mission
- SpaceX development contract for first Lunar landing system
- Mid-term future: Establishment of first human outpost on the Moon (in ~2030ties)
- Start of R&D projects of surface modules in the coming years



International Space Exploration Coordination Group (ISECG) and its coordinated efforts in space exploration of the Moon and Mars

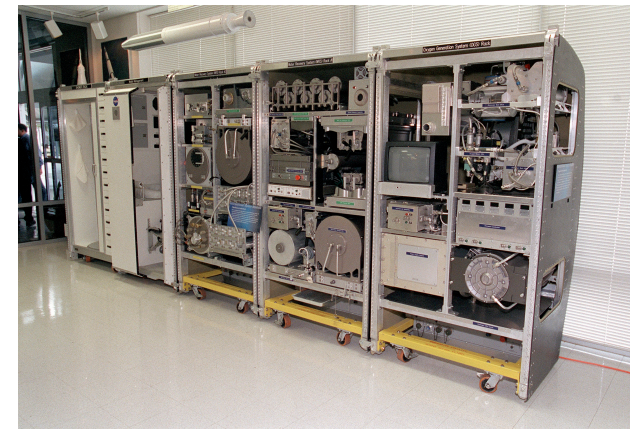
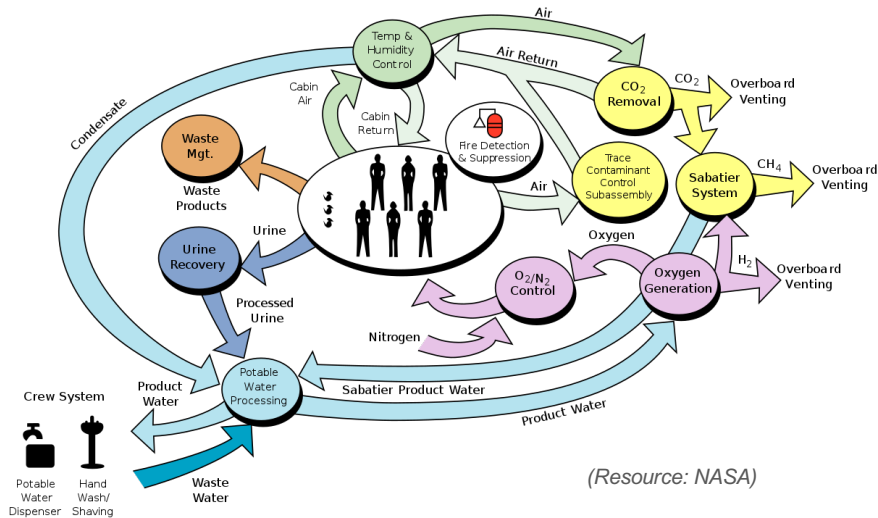


NASA roadmap for future human missions to the Moon (NASA)



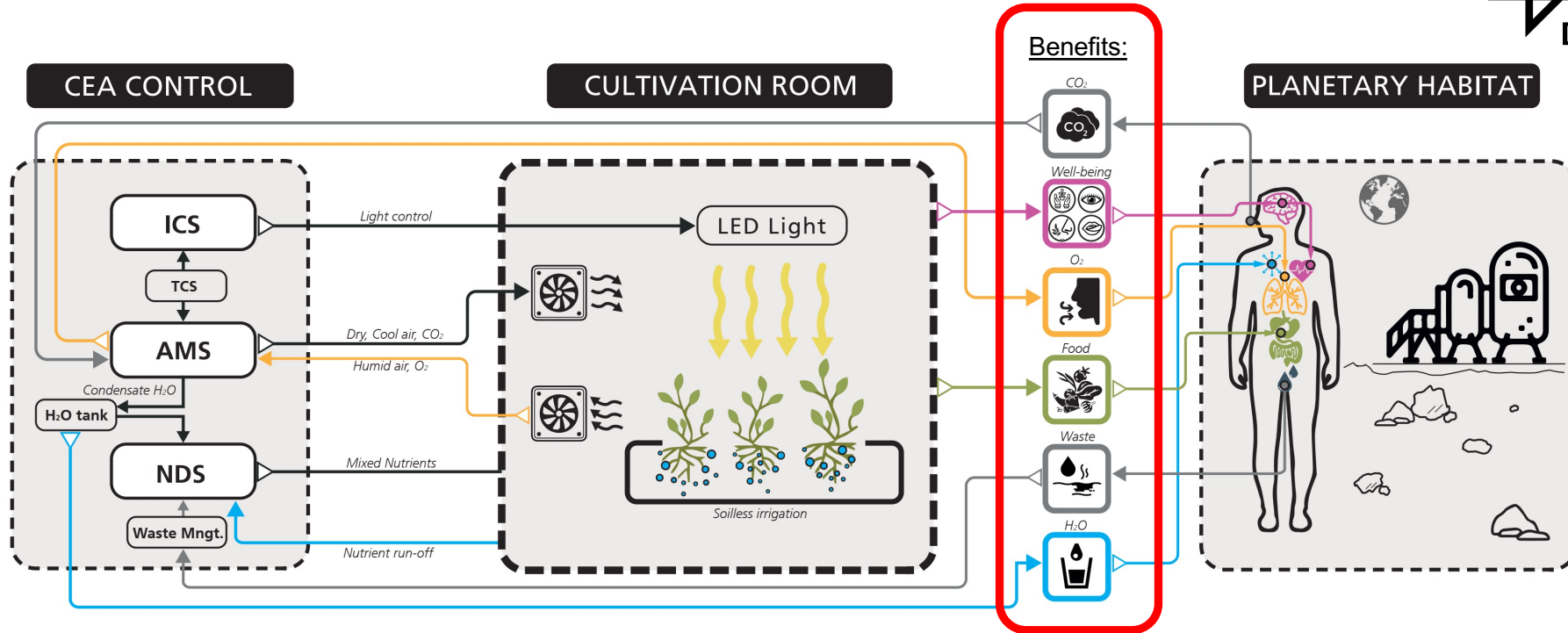
Lunar landing system (SpaceX)

# ISS Regenerative ECLSS



- 물 회수 시스템(WRS)과 산소 생성 시스템(OGS)을 주요 구성 요소로 하는 ISS 재생 환경 제어 및 생명 지원 시스템(ECLSS)은 물과 산소를 재생하고 재활용
- ECLSS는 가압된 거주 환경을 유지하고, 물 회수 및 저장을 제공하고, 화재 감지/진압을 유지 및 제공하며, ISS 내에서 생활하고 작업할 수 있는 통기성 공기와 편안한 분위기를 제공.

# DLR's Space Greenhouse: All-in-One Approach



- Controlled Environment Agriculture (CEA) Technologies
- Fresh food, CO<sub>2</sub> fixation, O<sub>2</sub> generation, water recycling, waste mgmt., well-being
- Necessity to fully integrate CEA technologies into one lightweight space system!



# LIVING IN EXTREME ENVIRONMENT



## PLANT CULTIVATION IN OUTER SPACE



- South Pole Food Growth Chamber in Amundsen-Scott South Pole Station (SPFGC) & EDEN-ISS: : 23 CM-h per week

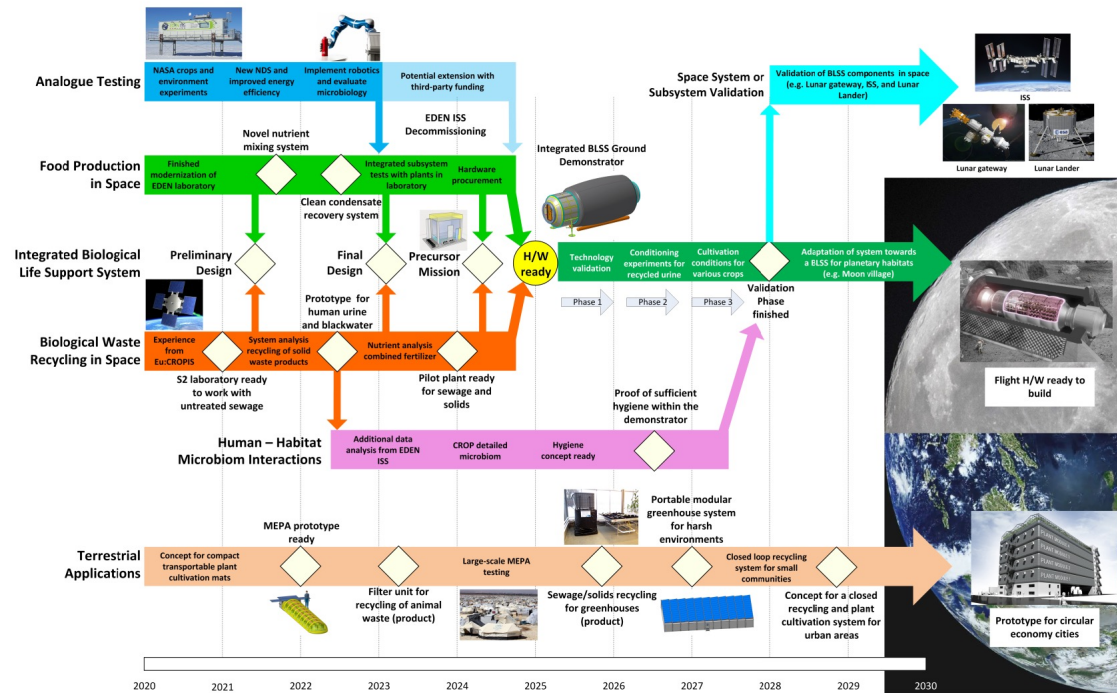
- In science fiction movies, it is often depicted that humans in extreme environments heavily rely on other forms of life, both physically and mentally.



# DLR Roadmap (2020 – 2030)

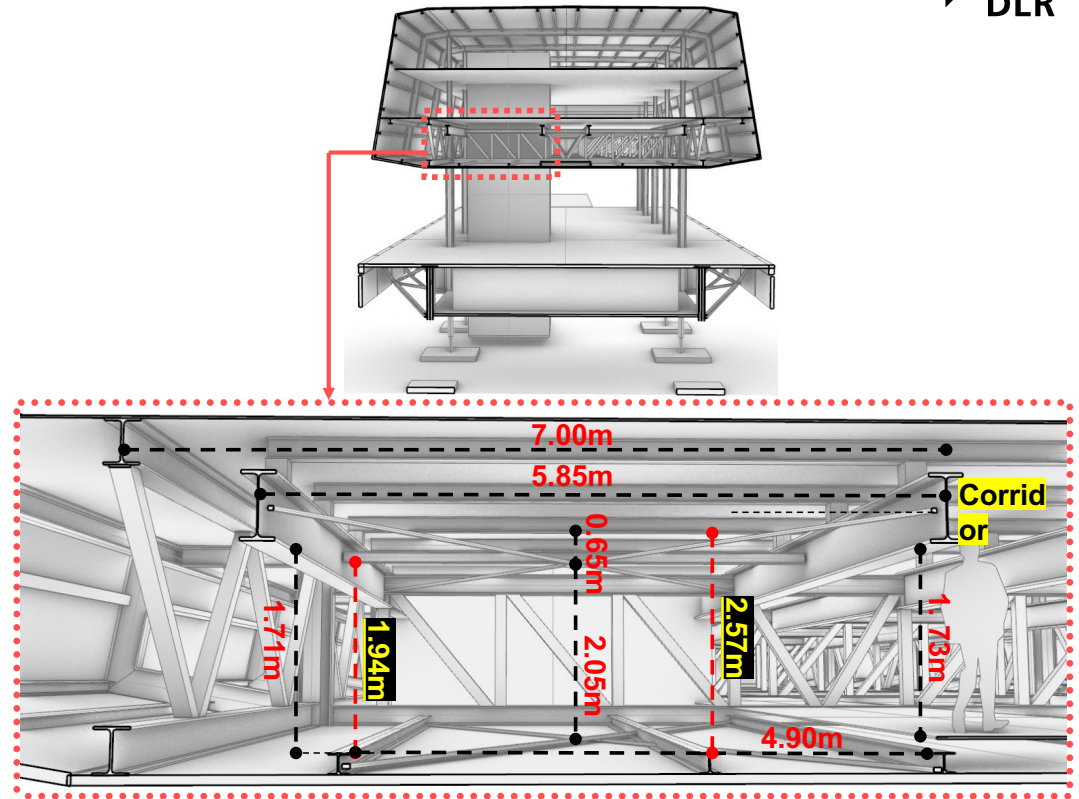
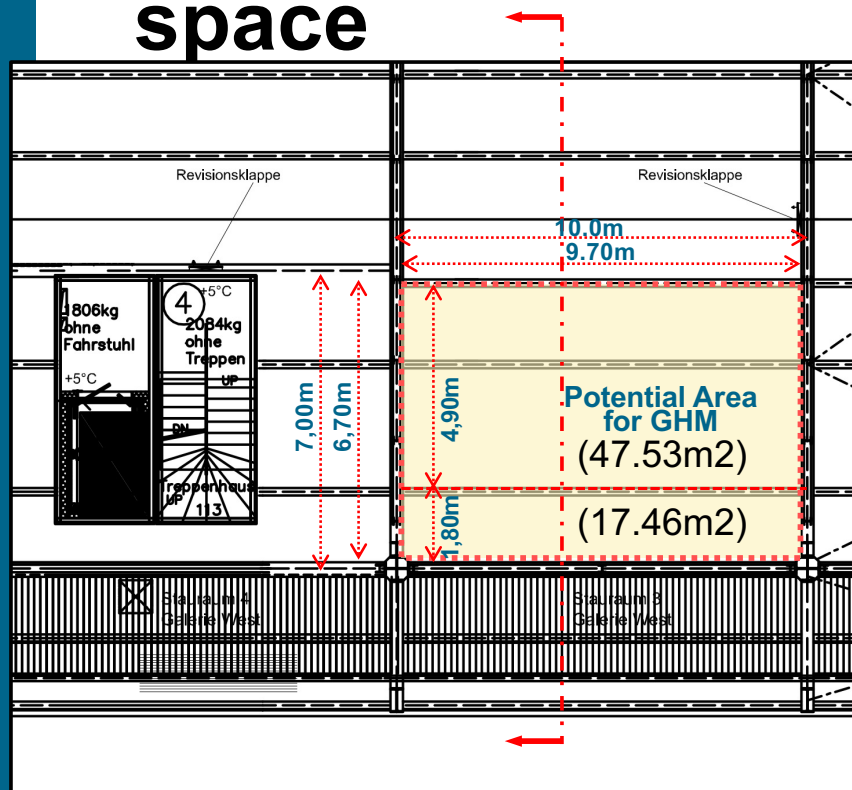


DLR Roadmap (Released in 2020)



- 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

# CHALLENGES = Limited space

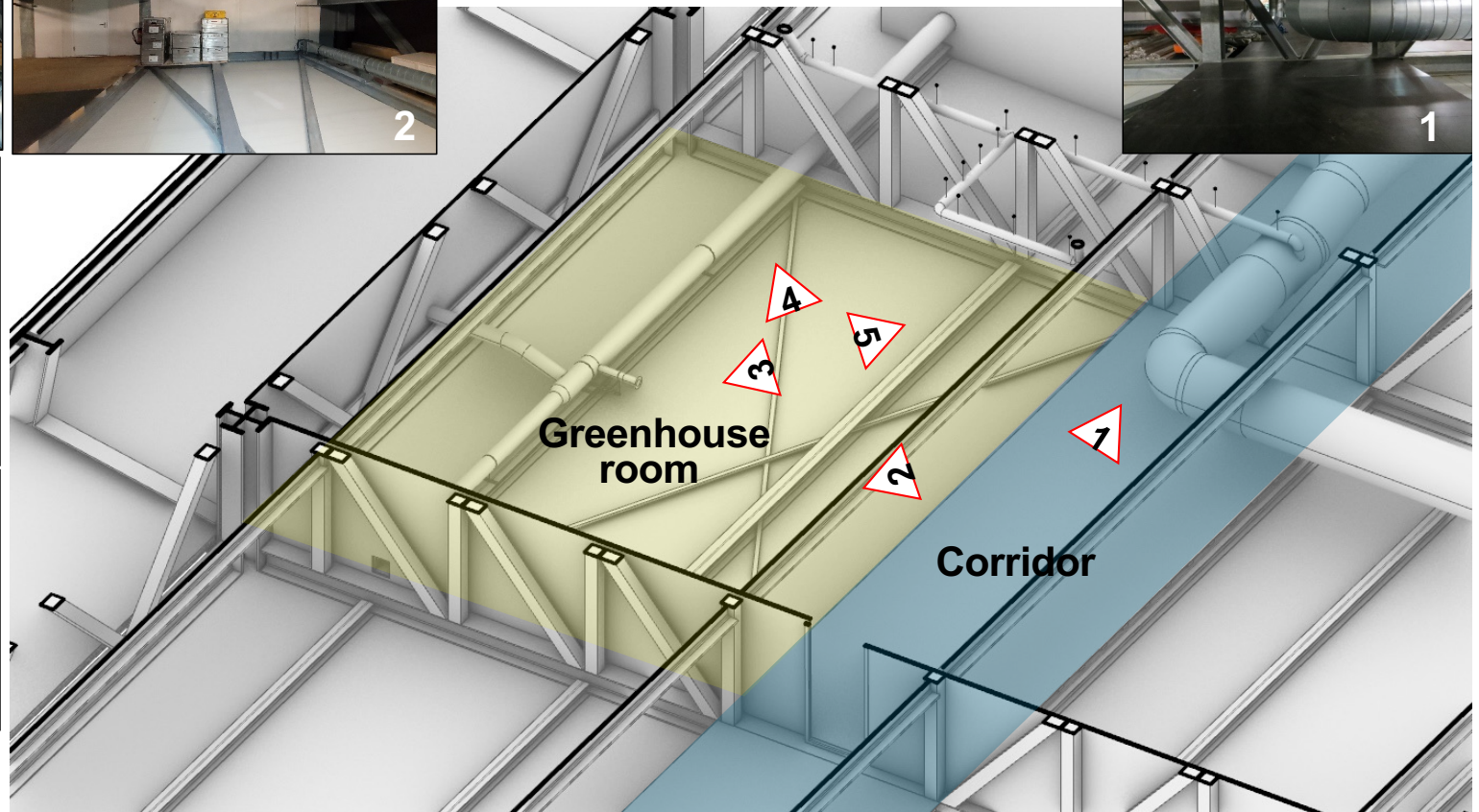


**Greenhouse Implementation**

\*Exact dimension of the room must be remeasured and checked before construction



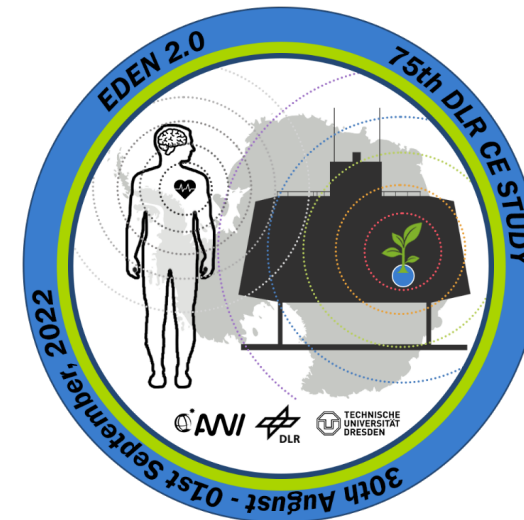
# EDEN2.0 IMPLEMENTATION ROOM



# Concurrent Engineering Study



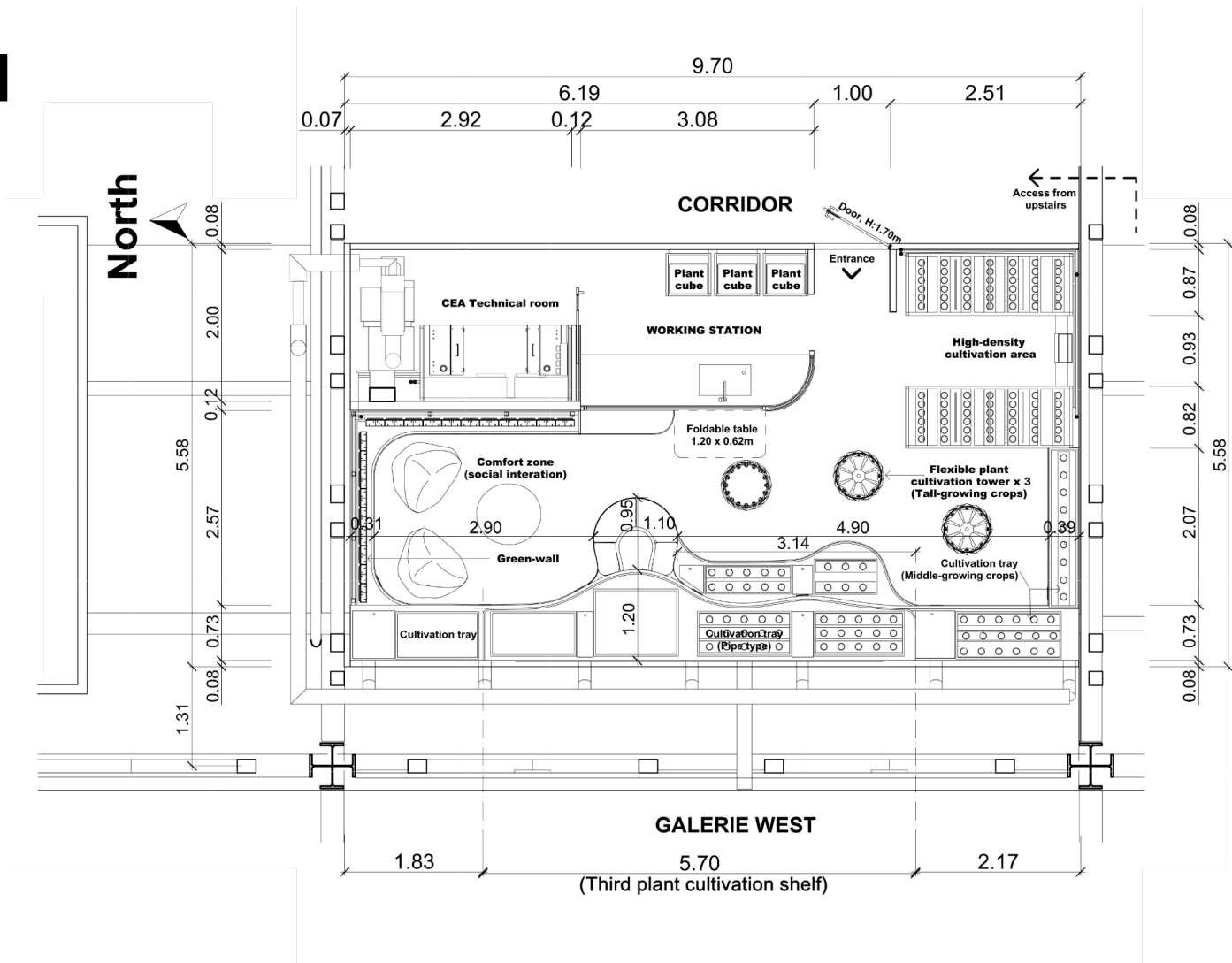
<CE-study group photos of the EDEN-II team>



- First combined design study with external partners (Oct. 2022)
- Outcome: Full pre-design, subsystem accommodation

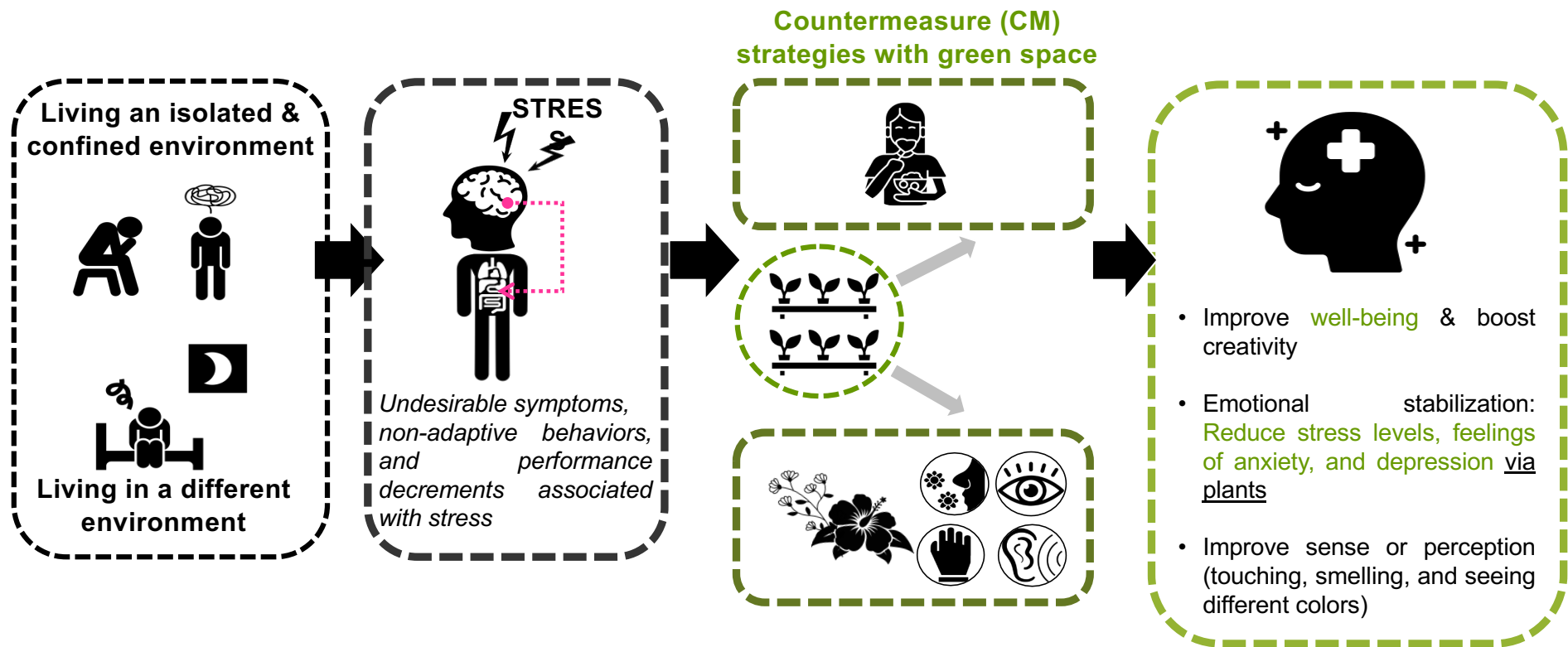
*\*CE Study: Intensive workshop to integrate all subsystems into one design at DLR*

# PLAN





# LIVING IN EXTREME ENVIRONMENT



# REQUIREMENTS



- Harmonize crops and garden plants
- Simple & Robust cultivation systems:
  - Less technology, more redundancy
  - Less maintenance & efforts for DLR & AWI (No operation training for crew)
  - Less energy consumption
- On-site operation time in the greenhouse: less than 2h / week
- Provide an effective design of the therapy garden for psychological health improvement
- Controllable from the Mission Control Center at DLR Bremen
- Flexible system transformation to being adapted by seasons: Summer & Winter mode
- One dedicated room inside of the station for climate control

# IMPROVING HUMAN MENTAL HEALTH



## THERAPEUTIC GARDEN CONCEPT (On Earth)

Philosophy of promoting the connection between nutrition and well-being of habitants



Ex) *Garden of Hope, City Hospital (USA)*

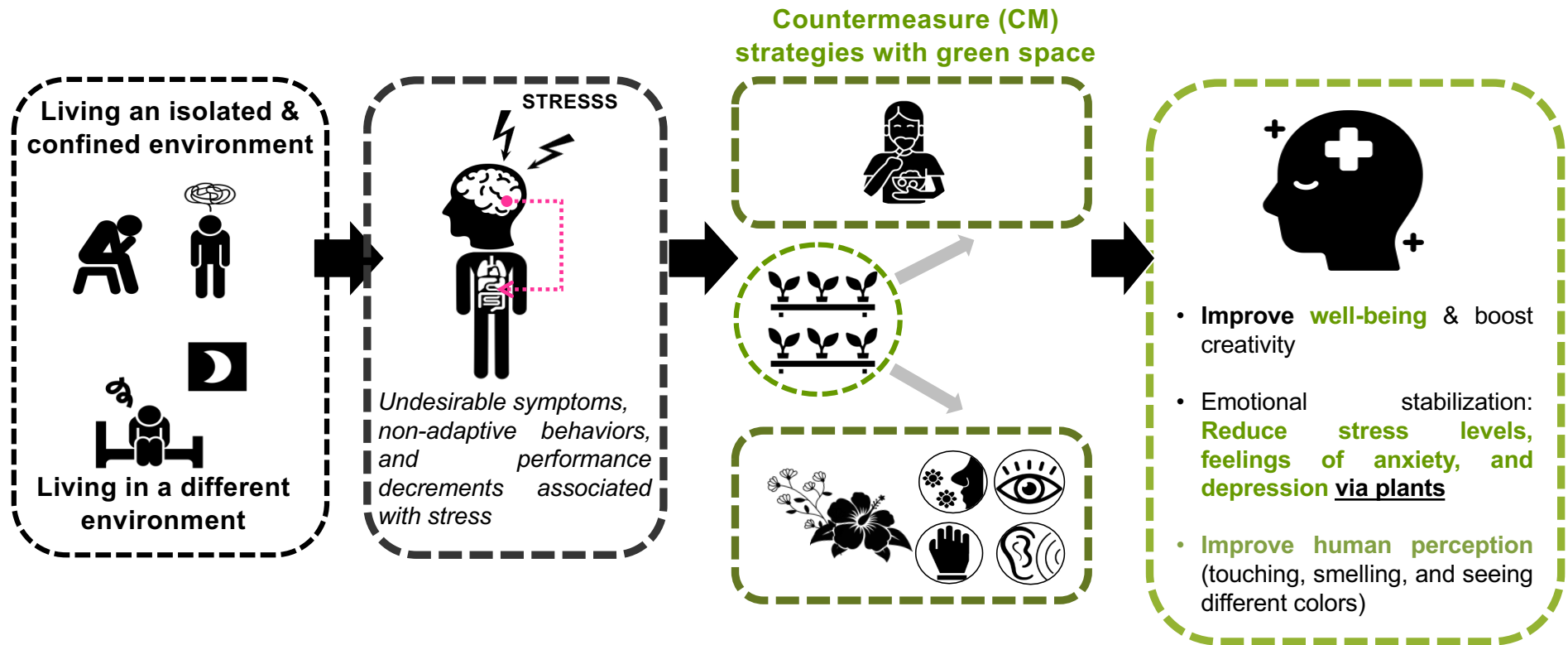
- Increased patient recovery rates by 20%
- Reduced anxiety levels by 30%
- Positive feedback from 90% of visitors

### □ Key Element:

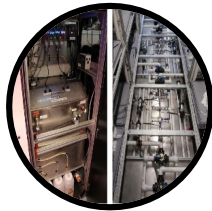
- **Nature & Greenery:** Diverse plants, aromatic herbs
- **Water Features:** Fountains, ponds
- **Pathways & Seating:** Accessible paths, benches
- **Therapeutic Zones:** Meditation, yoga areas
- **Interactive Elements:** Sensory gardens, healing art



# LIVING IN EXTREME ENVIRONMENT



# PROGRAMS



**CEA** (Controlled Environment Agriculture)  
**system, working area**

Intergrate ←



**Storage**

Intergrate →



**Social-Interaction  
area** (Resting place)



**Production  
Area**

- Monitoring (computer(s), monitor(s))
- Air management system
- Thermal / relative humidity control
- Temperature control
- Nutrient delivery systems
- Other technical / mechanical system



- Storage furniture



- Table(s)
- Chairs / couch
- Extended Experience using VR / AR



- Sensors
- Rack system
- Plant cube

# SYSTEM INTEGRATION

