Antarctic Greenhouse Module

Abstract

Humanity's plans to further explore the solar system requires the development of bio-regenerative life support systems (BLSS), fully incorporated into the habitat infrastructure. A Greenhouse Module (GHM) would contribute to food production, CO_2 reduction, O_2 production, water recycling and waste management.

It is essential to test these GHM technologies in a similar environment to space and with relevant mass flows in order to increase their Technology Readiness Level. The German Aerospace Center (DLR) is planning to design and operate a GHM test facility at an analogue test site. Therefore, the Antarctic Neumayer Station III of the German Alfred Wegener Institute (AWI) has been identified as an ideal testing ground.

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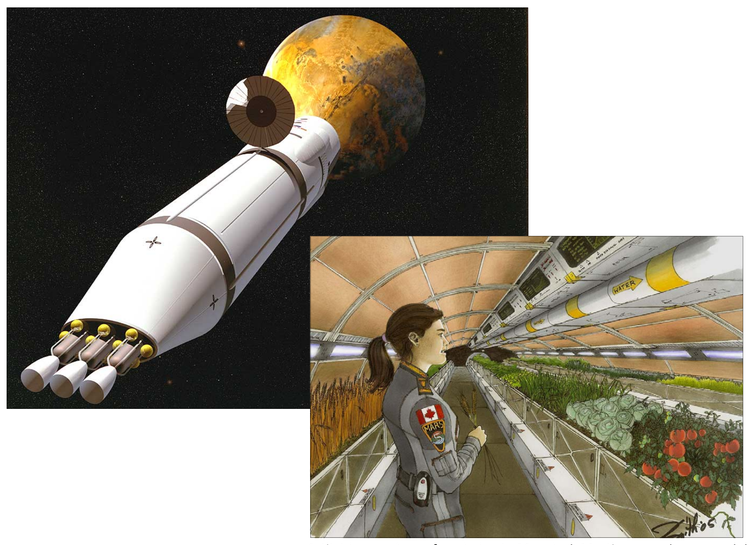
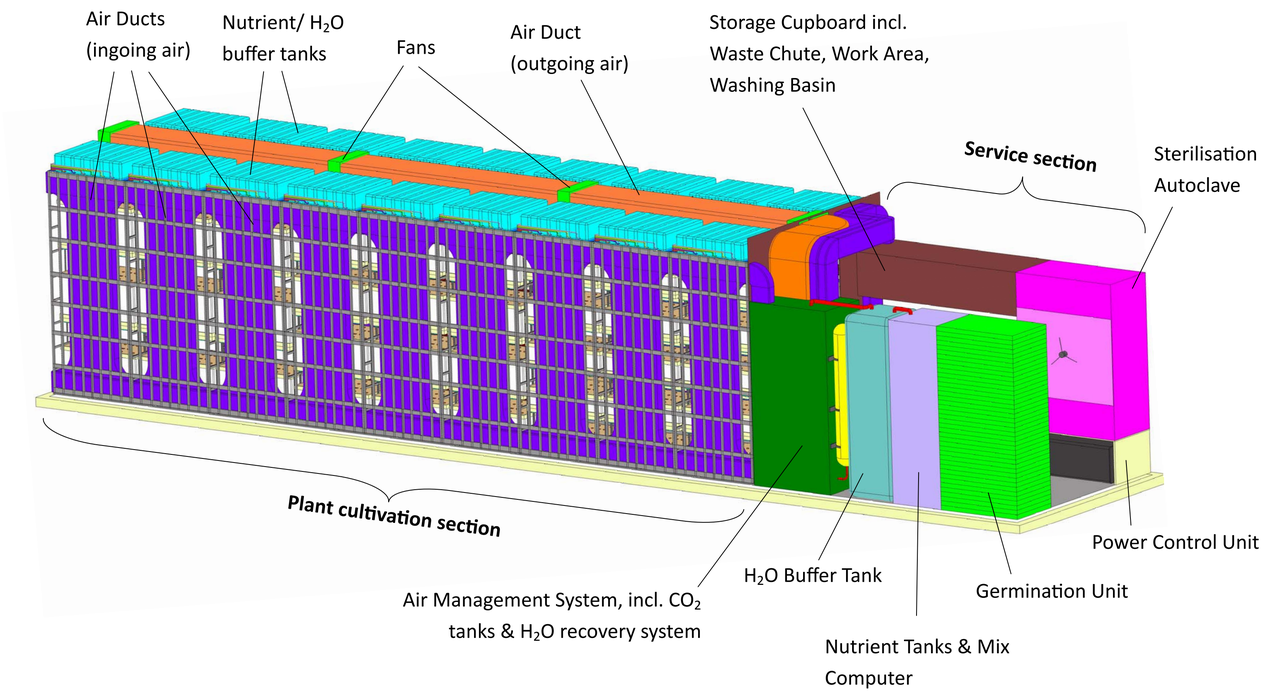
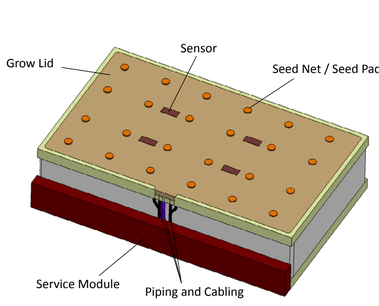


Artitst impressions of a mission to Mars incl. Martian greenhouse module

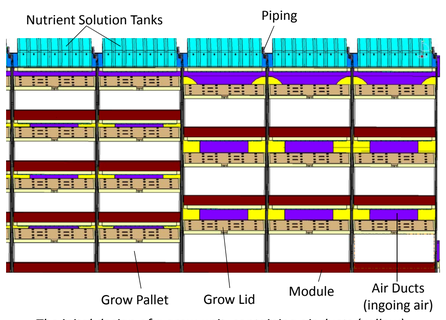
Design of the Greenhouse Module (GHM)



- For the external structure of the test facility, a standard 20 or 40 foot shipping container is used to reduce cost. This results in easy and inexpensive transportation and fast deployment to Neumayer Station III.
- The test facility is divided into a cultivation section and a service section. The container is thermally isolated for temperatures down to – 50°C. An airlock system is placed infront of the container (not shown in picture above).
- The *plant cultivation section* houses the different grow units, used for crop cultivation. Controlled Environment Agriculture (CEA) technologies provide proper environmental conditions for enhanced plant growth. The time-shifted approach is implemented between the different grow pallets to allow just-in-time harvest events. Multi crop strategy is foreseen, where target plants like for example tomatoes, raddish, lettuce, carrots grow in a concurrent way. Each grow pallet houses one single crop type in the same life-cycle phase.
- The *service section* accommodates support systems such as the germination unit, air management– and Nutrient Delivery System. Furthermore, an integrated work bench allows pre- and post processing of the grow pallets.
- The harvested crops shall be consumed by the Neumayer Station III crew as complementary food (=> supplement to the canned food)



Grow Pallet Design



The inital design of a grow unit, containing air ducts (yellow), grow pallets and lighting panels

Lettuce grown in a Grow Pallet

Analogue Test Site Features @ Antarctica

Important for every human space flight technology is an adequate testing in a respective environment similar to space. Since in-space validation campaigns are extremely costly, an inexpensive and fast testing at Earth Analogue Test Sites (ATS) becomes more and more desirable. Here, the ATS shall display one or more features, similar to the situation the crew has to handle on Moon/ Mars. The ATS at the Neumayer Station III exhibits the following analogue features:

Sterile Environment

Antarctica is one of the most protected and, from a biological perspective, sterile environments on Earth. This allows for further investigation of the microbial contamination patterns, resulting from the habitat and the human interaction.

Crew Size

A summer team (ca. 50-60) and a small winter team (ca. 7-9) stay at Neumayer Station III throughout the year. The winter team is isolated for nine months, which has a high similarity to future space mission crews.

Harsh Environment

Antarctica has extreme winds, heavy snow falls, temperatures below –50°C and seasonal dark periods of approximately 6 months.

Isolation

The crew has nine months of isolation and only one or two resupply rates a year. Effects on the psychological well-being of the crew are comparable with real long-duration space exploration scenarios (=> high mission fidelity).

Accessibility and Logistics

There are several international logistics agreements in order to supply the research station => affordable testing costs!

Habitat Interface

The Antartctic research station itself acts as a habitat, facilitating crew survivability on the Antarctic continent.

Human Dynamics and Technology Dependency

Neumayer Station III represents a good testing ground for future crew interaction relations and the investigation of Human-Machine-Interfaces.

GHM Subsystems

Structures, Mechanisms & Plant Compartment

- 20 or 40 foot shipping container
- 18 grow units

Nutrient Delivery System (NDS)

- High-yield, low water use plant production systems
- Real-time online measurements of ion-selective concentrations

Air Management System

- Temperature and humidity control system composed of COTS ducts, blowers, condensing heat exchangers, heaters and humidifiers
- Active CO_2 injection
- Innovative UV-C-LED water disinfection system

Lighting System

- High performance LEDs, combining a variety of monochromatic lights to create a spectrum specifically tailored to plant photosynthetic requirements
- Highly integrated panels and optimised with regards to mass, thermal load, volume and power demand

Health Monitoring & CDH

- The "Electric Nose" (E-Nose) allows for near real-time qualitative and quantitative microbial loads
- Transportable Modular Aerosol-based Decontamination and Disinfection System (TransMADDS) for decontamination purposes

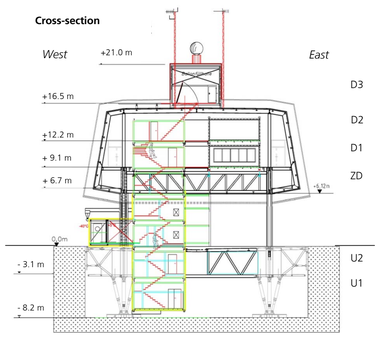
Prep.- & Post Processing Units

- Work bench (incl. washing sink, waste chute) for seedling- and harvest procedures
- *Sterilisation Unit* for cleaning and desinfecting the used grow pallets, grow lids and the aeroponic difussors

Neumayer Station III—Facts

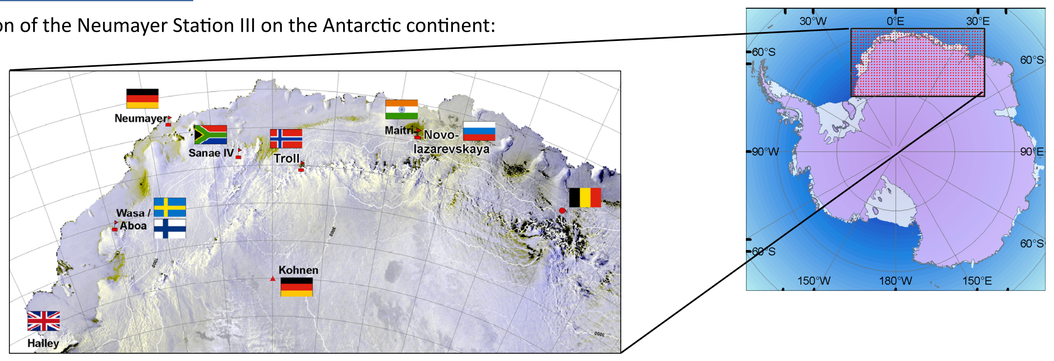
- German Antarctic research station, operated by Alfred Wegener Institute (AWI)
- Foundation winter 2007/2008, Construction winter 2008/2009, Inauguration 20 February 2008
- Three dimensional steel structure, comprises an underground section placed in a 76 x 26 m^2 trench in the snow
- 6 meters elevated platform surrounded by an insulated hull of 68 x 24 m^2 containing the two storied station

Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft



Access to Antarctica

Location of the Neumayer Station III on the Antarctic continent:



1. Cargo Ship and Pistenbulli

- The cargo ship *Polarstern* leaves in December from Cape Town, South Africa, where it travels to the Ekström Ice-Shelf.
- The cargo is transported the remaining 21km of the journey on 10 snow tractors (Pistenbulli).

2. Aircraft

- Scientists, all personnel for the season and special cargo travels to Neumayer Station III via aircraft.
- Allows for access to the continent from November to March.

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