

Service Section Design of the EDEN ISS Project

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The international EDEN ISS project aims to investigate and validate techniques for plant cultivation in future bioregenerative life support systems. To this end the EDEN ISS project partners aim to design and build the Mobile Test Facility, which consists of two modified 20 foot shipping containers. One of these shipping containers is designated the Service Section and houses the bulk of the subsystem components, such as the Air Management System and Nutrient Delivery System, as well as a rack-sized plant cultivation system, which uses a standard International Space Station payload form factor. The subsystems within the Service Section ensure that the approximately 12.5 m² of cultivation area in the second container, the Future Exploration Greenhouse, have the proper environmental conditions, nutrients and illumination for optimal crop growth. The EDEN ISS project concluded its main design phase with a Critical Design Review in March 2016, and thereafter proceeded into the hardware development and procurement phase of the project. This paper describes the final design of the Service Section at the start of the assembly, integration and testing phase, which will run until the complete Mobile Test Facility is shipped to Antarctica, where it arrives in December 2017, for a 12 month space analogue mission.

Nomenclature

AMS	=	Atmosphere Management Subsystem
AWI	=	Alfred-Wegener-Institute for Polar and Marine Research
CDHS	=	Command and Data Handling System
DLR	=	German Aerospace Center
EC	=	Electrical Conductivity
FEG	=	Future Exploration Greenhouse
ISPR	=	International Standard Payload Rack
ISS	=	International Space Station
MTF	=	Mobile Test Facility
NDS	=	Nutrient Delivery System
NM III	=	Neumayer III
PCDS	=	Power Control and Distribution System
TCS	=	Thermal Control System
UPS	=	Uninterruptable Power Supply

I. Introduction

The international EDEN ISS project started in March 2015, with the purpose of further developing plant cultivation technologies and investigating food safety and other operational procedures. Fourteen partners from eight countries in Europe, Canada and the US joined forces to build a space analogue greenhouse to validate plant cultivation technologies during a twelve month analogue mission at the German Neumayer III (NM III) research station in Antarctica¹. Early design concepts for an analogue space greenhouse in Antarctica from the project leading organization, the German Aerospace Center (DLR), date back several years before project inception². In September 2015 a concurrent engineering study was carried out in order to generate a preliminary design of the Mobile Test Facility (MTF), the facility that houses the greenhouse and all of its subsystems³. As preparation for the design study, early trade-offs and top-level design drivers for Antarctic greenhouses were identified⁴. The designs of past and current Antarctic greenhouses⁵ were also taken into account in the design of the MTF. A plant selection

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methodology was developed and employed in order to select the plant species to be grown during the twelve month analogue test campaign⁶.

The preliminary design of the MTF has been further improved by the project consortium over the course of 2016. In spring and summer 2016 the manufacturing of the MTF outer structure, the greenhouse subsystems and the platform on which the MTF will be located in Antarctica were completed. In January 2017, the platform was subsequently deployed at the designated site around 400 meters away from the Neumayer III. The MTF outer structure, consisting of two customized containers, was delivered to the DLR site in Bremen in October 2016 for the integration of the different subsystems and components. The first installed components were the power control and distribution system (PCDS), including a large portion of the harnessing, and the shelf-like structure of the plant cultivation system inside the Future Exploration Greenhouse (FEG). At the end of October 2016, the nutrient delivery system (NDS) and the control and data handling system (CDHS) were delivered and integrated into the MTF. At the beginning of December 2016, the plant growth LEDs were installed and then tested during the first week of January 2017. At the end of the same month, the thermal control system (TCS) and a computer rack were assembled and mounted in the Service Section. In February 2017 the atmosphere management system (AMS) and in March 2017 the ISS rack-like plant cultivation system and the work desk were installed.

A several months long testing program was commenced at the end of March 2017. This testing program involved tests of individual MTF components and subsystems as well as longer term testing in which several growth cycles with actual plants are performed. The EDEN ISS project schedule foresees the delivery of the MTF containers for shipping to Antarctica in October 2017 and the arrival in Antarctica by mid-December 2017. This paper describes the final design of the Service Section which makes up 50% of the volume of MTF. The design is explained in detail using technical drawings and photographs of the actual hardware installed in the MTF as of March 2017.



Figure 1. Illustrative impression of the MTF on its platform (Left image, Credit: LIQUIFER Systems Group). The MTF at DLR Bremen in January 2017 with the integration tent on the right side (Right image, Credit: DLR).

II. Mobile Test Facility Design Overview

The EDEN ISS MTF consists of two customized 20 foot high-cube shipping containers. The two container approach was necessary, because the logistic chain from Germany to the Neumayer III research station is based on that format.

The Service Section container consists of the Cold Porch, which serves as a buffer between the external environment and the working area, and the Service Section which houses the bulk of all of the greenhouse subsystems and also provides a work desk with an integrated sink and storage space. An ISS rack-like plant production facility⁷ is also located in the Service Section. The Service Section has a large window in the North wall from which one can observe Neumayer III from a distance, see Figure 2. The design of the Service Section container is described in detail in the following sections of this paper.

The second container houses the FEG which is separated from the Service Section by a wall and a sealed door. The FEG is the main plant cultivation room of the MTF. The design of the FEG is described in detail in a separate publication⁸.

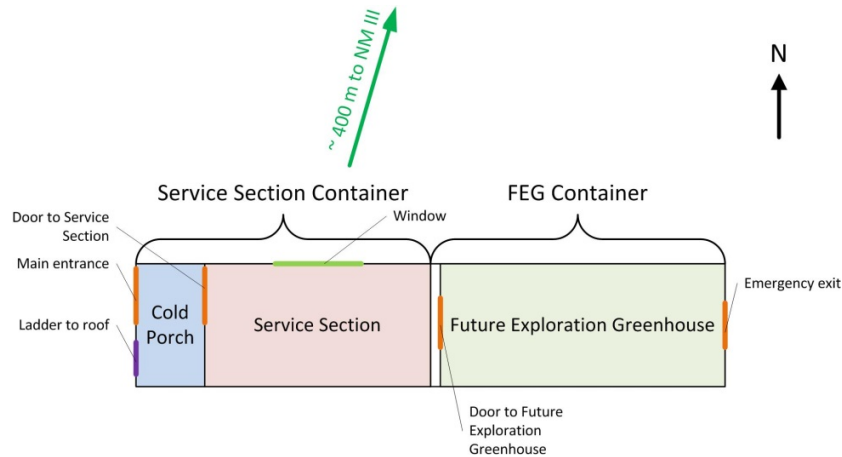


Figure 2. Overview of the EDEN ISS MTF main elements. Credit: DLR

Both containers include rock wool insulation (~80 mm) and wood plates (10 mm) attached to the inner walls. The inner side of the walls and the ceiling are covered with white high pressure laminate plates to provide a smooth and clean surface. Furthermore the plates are fire retardant and have a special top layer which greatly reduces microbial growth. The floor of the container is insulated with polyurethane foam (~120 mm). A stainless steel basin is installed on top of the original wood panel floor in both containers. The basins are 100 mm high and cover the complete floor of the container. This design decision is made in order to avoid potential spill water running into the container wall construction. The basins collect all leakage water and from there it can be pumped to the wastewater tank.

Another special design choice for this project is the sub floor space. A raised floor made of anodized steel bars is installed inside the basins. The space between the container floor (basin) and the corridor floor, is 300 mm high and allows for pumps, water and cooling fluid pipes and air ducts to be placed below the lowest cultivation surface.

The floor plates are removable to facilitate maintenance on sub-floor components. In the Cold Porch and Service Section, floor plates are solid for crew comfort, while in the FEG the floor plates consist of stainless steel grates to improve air circulation between the sub-floor area and the main environment.

The interfaces between the MTF interior and exterior, for power and data lines, as well as some liquid and gas piping, are all located in the Service Section area. The selected approach for these openings was the use of GK-Packsystem interfaces, which consist of welded frames which are closed off using rubber blocks to ensure an airtight seal. Additionally, there is an opening for fresh air inlet on the South-facing side of the Cold Porch.

To facilitate the wall-mounting of certain components, wood plates were incorporated into the wall design of the Service Section container at designated areas along the North wall.

III. Service Section Design

The Service Section contains the majority of the subsystem components which monitor and control the environmental conditions within the MTF and ensure optimal conditions for plant growth in the FEG through atmosphere management, nutrient delivery and specific illumination settings.

The internal layout can be seen in Figure 3 and Figure 4 which presents section views of the North- and South-facing sides of the Service Section. As indicated in the images, the North-facing side accommodates the power control and distribution system, the main part of the command and data handling system as well as the main work space for crew operations.

On the other side of the Service Section, the nutrient delivery system, thermal control system and the atmosphere management system are integrated into a single rack structure. Next to this rack is a plant cultivation demonstrator for future use on the international space station (ISS). The design of this demonstrator, based on an international standard payload rack (ISPR), as used on the ISS, has previously been presented in detail⁷.

In the Cold Porch, this side of the container holds a storage cabinet with, among other things, cleanroom clothing for the crew. Above this cabinet, the top section of the cold porch is occupied by the fresh air supply system. Below the floor panels, the Cold Porch holds a fresh water and a wastewater tank.

The design aspects of the main subsystems will be elaborated in the remainder of this paper.

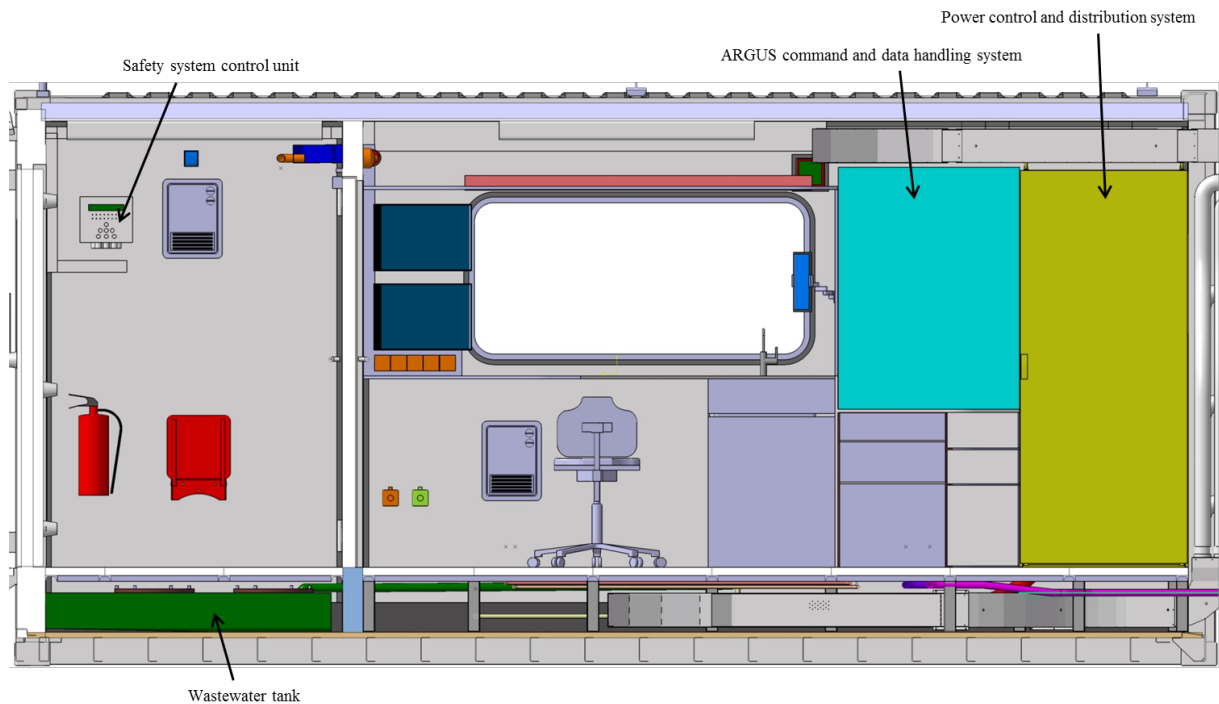


Figure 3. Section view of the North-facing side of the Service Section interior. Credit: DLR

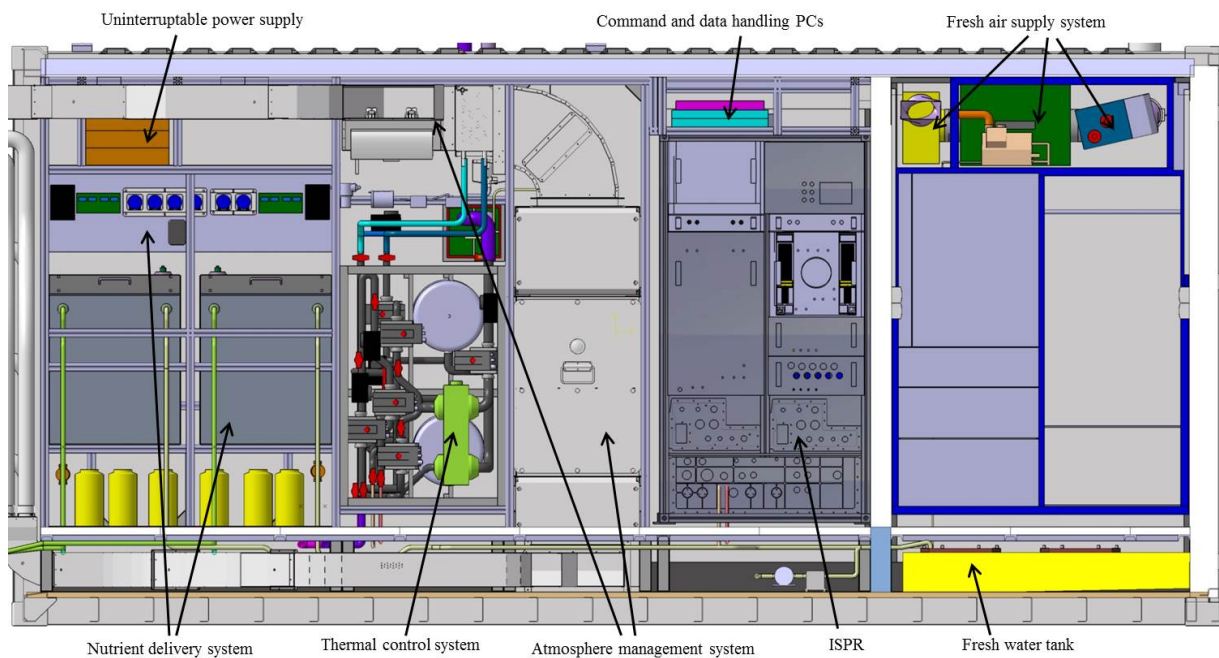


Figure 4. Section view of the South-facing side of the Service Section interior. Credit: DLR

A. Power Control and Distribution System

The power control and distribution system consists of the main power box, an energy measurement system, cable channels and power cables, and the internal and external lighting (excluding the plant illumination system). The main power box is located on the north side of the service section adjacent to the wall to the FEG. The box holds all

fuses, relays, wattmeters and DC converters and splits the incoming three-phase line from Neumayer III into lines for each subsystem, which are then split into lines to the different components.

The power box is 850x400x2000 mm, weighs around 300 kg and has a glazed door at the front. The main power line coming from the Neumayer III station enters the cabinet through the North-facing wall close to the bottom of the cabinet. The power distribution cables leave the cabinet through the roof of the cabinet, except for the power lines for a water boiler and fresh water pump which are leaving the cabinet through the bottom.

Figure 5 gives an overview about the internal setup of the power box. The electrical components are covered by six large plastic panels, which can be removed individually. Behind the top most panel is the output connector for the 230 VAC lines and the 24 VDC lines and the connectors for the control inputs for the relays. Furthermore, the communications module and display of the energy measurement system are located in and behind the topmost panel. The four panels in the middle section of the power box cover the distribution network, relays and fuses of the different subsystems. Each subsystem has a main fuse/switch to shut down the complete subsystem and fuses/switches for each component or a group of components within the subsystem. All subsystems except the command and data handling system (CDH, Coms, OPS) and the common equipment also have a main relay to control the whole subsystem. Single relays are built in for the components which need to be controlled by the Argus control system. Close to the bottommost panel are the main switch for the whole MTF, and the Digiware measurement modules. The bottommost panel covers the connectors for the main supply line on the left side, the 24 VDC fuses in the middle and two heater controllers on the right side. Furthermore, there is a big 24 VDC transformer on the right side behind the heater controllers.

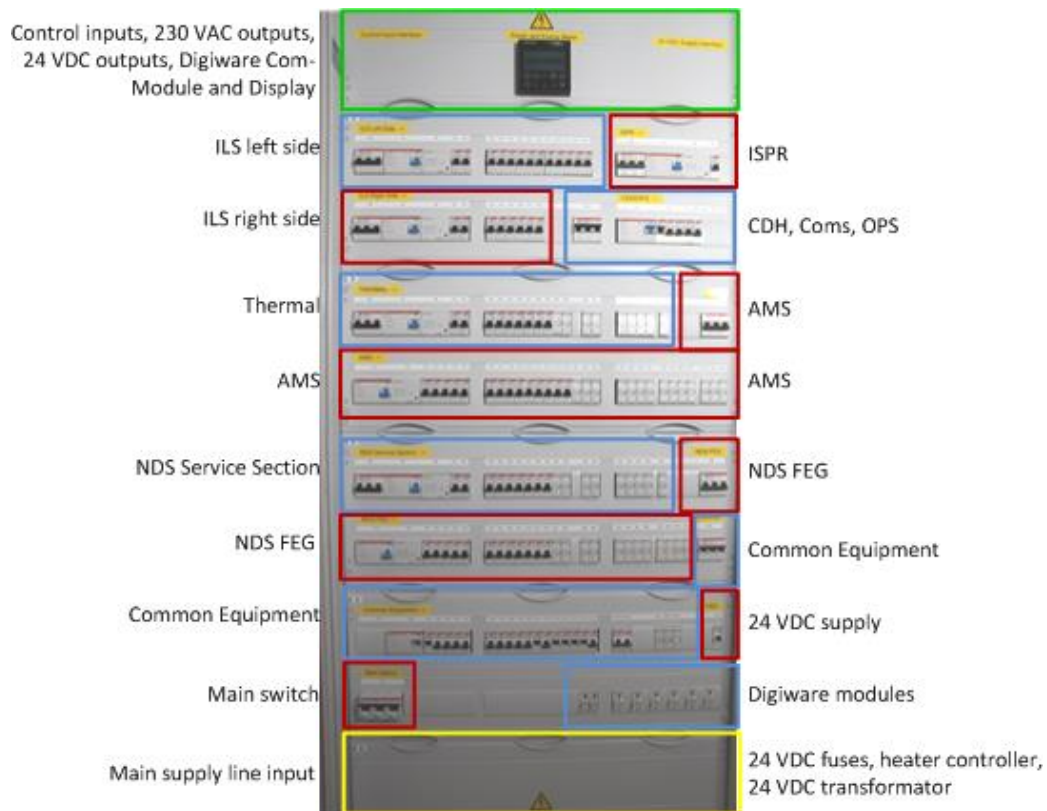


Figure 5. Internal setup of the Power Control and Distribution System. Credit: DLR

The average power demand of the MTF calculated over one year is around 11.5 kW. However, the plants require a certain photoperiod-darkperiod cycle, where photoperiod means the plants are illuminated and darkperiod means that the plants are not illuminated. The cycle results in a different power demand during photoperiod and darkperiod, because some subsystems are not running during the latter time frame, or only at partial capacity. During photoperiods the average power demand is around 14 kW and during the darkperiods around 6.7 kW.

Potential power shortages and voltage fluctuations have to be buffered to avoid the uncontrolled shutdown of the command and data handling system and the communication between the MTF and Neumayer. Therefore, a backup

power supply, or uninterruptable power supply (UPS), is installed within the MTF Service Section. The UPS is located in the top compartment of the NDS rack on the South wall.



Figure 6: UPS mounted in the top compartment of the NDS rack. Credit: DLR

The UPS will only cover certain critical elements pertaining to the CDHS, listed in Table 1, and only for a maximum of about 20 minutes. This maximum duration during which the equipment listed below needs to be supplied solely by the UPS is estimated based on values from equipment currently installed at Neumayer. The station UPS lasts for around 30 minutes and the UPS of a nearby facility, SPUSO, lasts for 15 minutes.

Table 1: Equipment supported by the UPS

Equipment	Amount
Argus Server PC	1
Camera Control PC	1
Argus System	1
SS switch	1
Patch antenna (via PoE SS switch)	1
FEG switch	2
WiFi access point (via PoE FEG switch)	1
24 VDC supply inside power box	1
Safety systems (via 24 VDC supply)	1
Screens	2

The UPS is a modular system. It consists of one main module (top most module in Figure 6) and three extension battery packs. The UPS is able to provide 230 VAC over eight outputs at the back of the main module. The UPS has a built in display on the front side of the main module which can show different parameters (e.g. battery load status, power load status). The UPS main module can also be equipped with a network card to connect it to an Ethernet switch for data exchange.

B. Atmosphere Management System

The atmosphere management system consists of two separate units, the fresh air supply system for the Service Section and the AMS rack for the FEG. The environmental conditions within the cold porch are not actively controlled, aside from a heater which maintains the temperature above a set minimum.

The fresh air supply system, shown in Figure 7, regulates the temperature and relative humidity conditions in the Service Section. The system aims to cool the air in the Service Section through air mixing, rather than full air exchange. The air inlet has an H-shaped cowl, to prevent snow from entering the facility. A flow control valve prevents external air from entering the facility until the internal temperature of the Service Section reaches the maximum allowed temperature of 27° C (or 18° C at night). At this point, the valve will be opened and air enters the air duct. The air is first heated by heater elements before passing through a pre- and HEPA filter. Depending on the external air temperature, the heater power will be regulated to achieve a consistent fresh air temperature of 5° C. A fan ensures sufficient pressure head to overcome the losses in the system. Finally, the air enters the Service Section through the louver located just above the door separating the cold porch and the Service Section. An ultrasonic

humidifier, with a capacity of 0.5 kg/h injects moisture into the air to ensure relative humidity remains within the desired range of 25-30%. The relative humidity in the Service Section is kept low in order to ease the transition between the interior and exterior conditions for the crew. The fresh air supply system is sized for an air flow rate of 150 m³/h. An air outlet was originally included in the Service Section, but ultimately discarded. On account of the relatively low air flow rate as well as expected air exchanges between the Service Section and the external environment, as a result of crew movement, a dedicated air outlet was deemed non-critical.

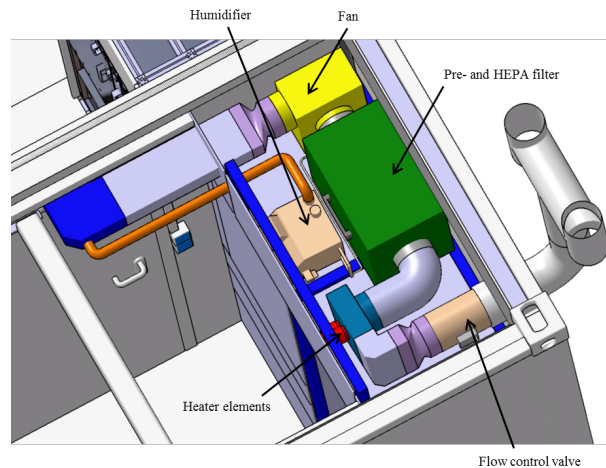


Figure 7: Fresh air supply system. Credit: DLR

The Service Section also houses an AMS rack for the atmosphere management of the Future Exploration Greenhouse. Barring interactions between the two areas as a result of crew entering and exiting, the FEG will function as a closed environment. The AMS rack in the Service Section counteract the deviations of the air from the nominal conditions, as a result of gas exchanges and thermal loads, by filtering and dehumidifying the air in the FEG. The nominal flow rate of the system is 1400 m³/h during photoperiod and 800 m³/h during dark periods, which is achieved via two fans, located above and below the filter casing, as seen in Figure 8. The maximum achievable flow rate was validated using computational fluid dynamics analysis of geometrical and component-related pressure losses.

A liquid-air cooling coil is used to dehumidify air coming from the FEG, with the recovered condensate water subsequently filtered, sterilized and pumped to the fresh water tank in the cold porch. A pre- and HEPA filter are implemented in the design to mitigate the risk of undesirable micro-organism growth in the FEG. Additionally, a VOC filter will remove trace gases, such as ethylene, from the air to prevent a build-up which otherwise could result in adverse effects on plant and crew wellbeing.

For increased plant yield, the FEG environment will have an elevated CO₂ level. This will be achieved via injection of CO₂ from bottles, stored external to the facility for safety, into the AMS rack in the Service Section. The nominal level will be 650 ppm, with a maximum of 1500 ppm during a 24 hour period.

O₂ levels will be monitored, but no methods are implemented in the AMS rack to reduce the O₂ level. An analysis based on expected crew work time in the FEG indicates that O₂ levels will remain within an acceptable range.

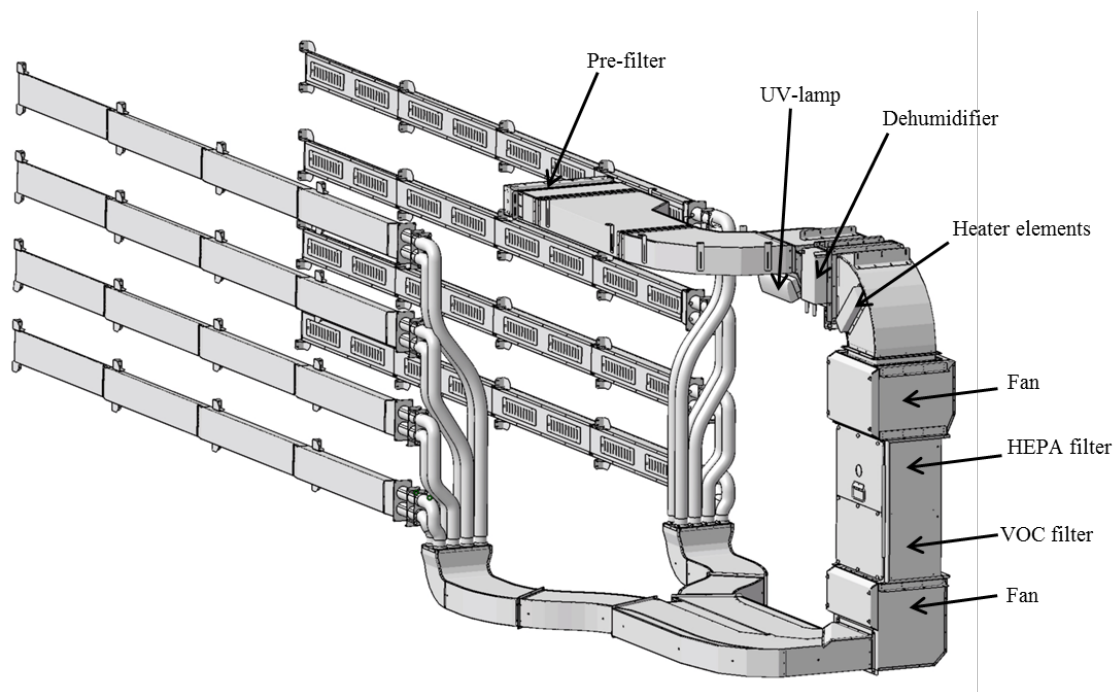


Figure 8: AMS rack with ducting. Credit: DLR

C. Nutrient Delivery System

The overall NDS design is based on an existing hydroponic concept, developed by DLR Institute of Space Systems, that is a hybridization of classic NFT and aeroponics. The system utilizes standardized 400 x 600 x 120 mm food grade polypropylene shipping containers (growing trays), adapted covers and high pressure misting to achieve an appropriate degree of plant water delivery and root zone oxygenation.

The main component rack, see Figure 9, located within the Service Section contains two stainless steel 250 liter nutrient solution tanks with internal primary variable speed mixing pumps. Sensors include pH, EC, temperature, water level and flow rate sensors, while manual system disinfection can be achieved with an integrated ozonation system. In order to make maintenance and calibration simpler, pH and EC probes are suspended directly in the nutrient tanks. Stock nutrient reservoirs and acid/base control solutions are contained below the main tanks, with the corresponding dosing pumps mounted above the tanks. Both tanks have redundant sensors to ensure system reliability. Each nutrient tank is operated independently and can have different nutrient solution compositions that depend on experiment and plant requirements. Each nutrient tank has two separate stock supply tanks (traditionally known as A and B, but in this case the second tank will have solutions C and D available), but both are supplied from the same acid and base reservoirs for pH control. All components in the NDS Service Section rack are placed to allow easy access and simplified maintenance.

The main NDS rack feeds the cultivation systems located in the FEG, which contains four growing rack systems on each side of the central corridor. Each rack can be operated/isolated separately as each has its own high pressure primary pump for delivery to the growing tray nozzles. Each rack can be fed by either nutrient tank through manually operated 3-way valves on both delivery and nutrient return. The 3-way valves are located in the floor of the FEG and are accessible via removable floor panels. Solution compositional changes should not take place very often, so access through flooring panels is appropriate and helps alleviate space constraints.

Return of the nutrient feed stream from the growing tray is by a combination of gravity return to a central lower reservoir and active pumping with submersible pumps which engage in response to water level sensors located within the sump reservoir. The entire NDS solution loop is closed (recirculating). Water lost to evaporation and transpiration is recovered by the condenser located in the Atmosphere Management System rack in the Service Section. Recovered water is directed to the fresh water tank located in the floor of the airlock. Additional water from the fresh water tank is injected into the nutrient tanks in response to the predetermined tank water level, or as required for nutrient composition control (i.e. lower EC). A cooling loop is included in the nutrient tank design, but

will only be implemented if excessive temperatures are encountered in the nutrient feed during pre-deployment testing.

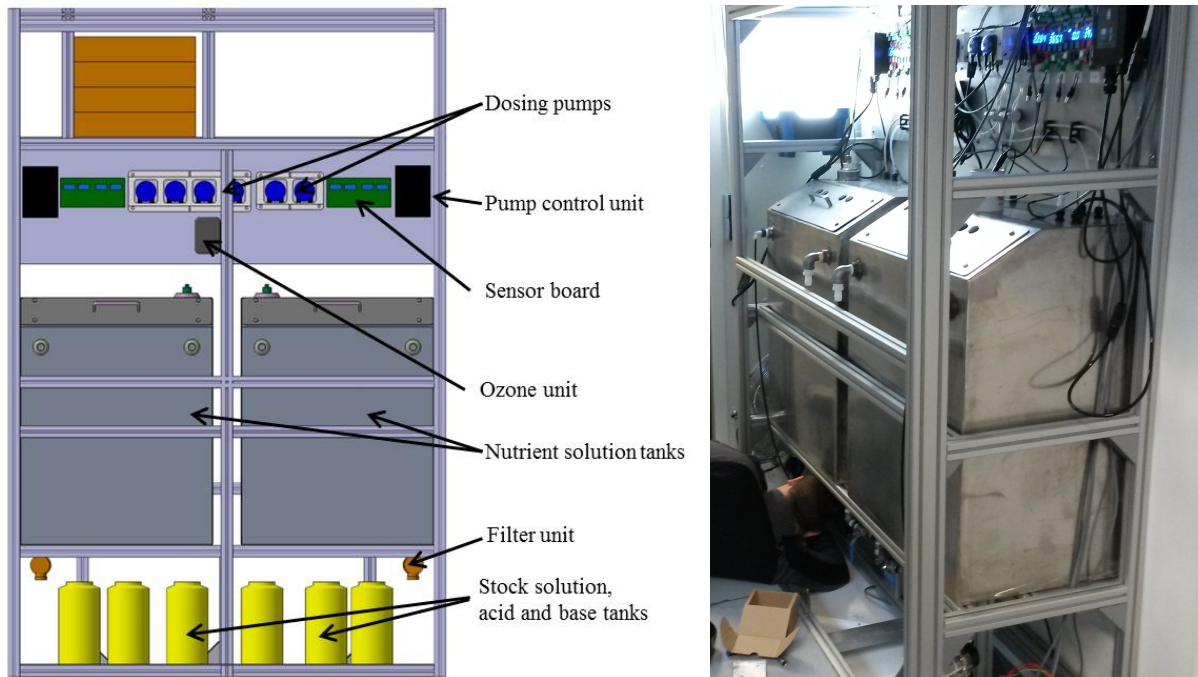


Figure 9: CAD image of NDS rack (Left image). NDS rack integration in the MTF (Right image). Credit: DLR

Both the fresh and waste water tanks were custom made to fill the space in the sub-floor in the air lock. Each tank holds approximately 300 liters and has integrated float sensors that are monitored by the Argus Control System to indicate a full condition (waste tank) or full and near empty conditions (fresh water tank). The fresh water tank pump consists of a self-priming pump and accumulator tank to reduce pump demand and to increase pump lifespan. The fresh water tank feeds water to the sink and to the NDS bulk nutrient tanks. Water is dispensed either through a tap at the sink, or via feedback response through Argus from the internal water level sensor in the NDS bulk nutrient tanks. Control of water flow in this case is by Argus controlled solenoid valves. When water levels fall below the desired set-point in the NDS tanks, fresh water will fill the tank until the desired level set-point is reached.

D. Thermal Control System

The thermal control system consists of the insulation which is incorporated into the containers and an active system, see Figure 10, which uses liquid cooling loops to transport heat to an external heat rejection unit. Additionally, heaters are present in the different sections of the MTF to ensure the temperature does not drop below 5°C in case of subsystem failures.

The thermal control system has to actively dissipate the bulk of the heat produced inside the entire MTF. Specifically, the thermal system will dissipate the heat from three sources: the ISPR, the AMS and the LED panels in the FEG. A water and food-grade glycol mixture will be used to transport heat from the sources to liquid-liquid heat exchangers and to subsequently transport the heat from the heat exchangers to a roof-mounted heat rejection unit, known as a free cooler.

An overview of the thermal loads (including margins), supply temperature, return temperature and flow rate for the three cooling loops is presented in Table 2.

Table 2: Thermal loop characteristics

Heat source	Supply temperature	Return temperature	Flow rate	Thermal load
AMS	8°C	15.2°C	1100 kg/hr	6600 W
ISPR	20°C	25.9°C	190 kg/hr	1300 W
LED	20°C	25.9°C	~440 kg/hr	3000 W

The AMS thermal loop and the ISPR and LED thermal loop have a similar architecture. A pump with an expansion vessel forces a coolant liquid through the system (AMS dehumidifier, LED cold plate, or ISPR) and then towards a plate heat exchanger. The AMS loop will have a dedicated plate heat exchanger, whereas the LEDs and the ISPR flows will be connected with a single plate heat exchanger for both loops combined. A number of sensors are incorporated to determine temperature, flow rate and pressure.

Temperature regulation of the thermal loops will be done by mixing the in- and backflows using three-way valves. For the AMS cooling coil, the volume flow will also be controlled via three-way valve, whereas for the LED panels and the ISPR flow regulation valves will manage the flow rate through the system.

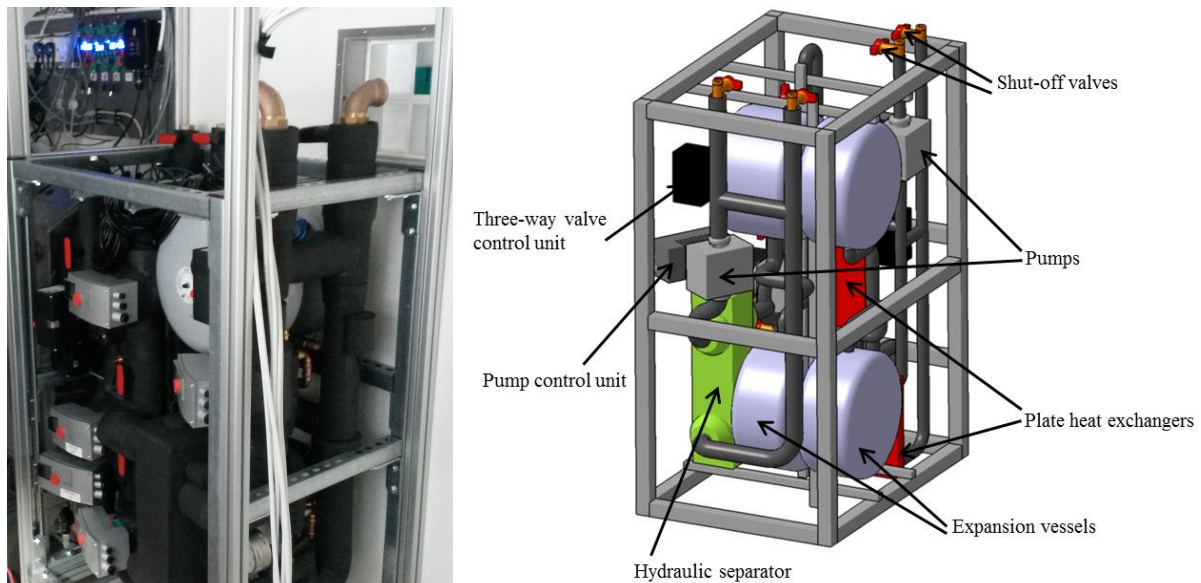


Figure 10. Thermal control system in the MTF (Left image). Thermal control system CAD model (Right image). Credit: DLR

The transport architecture handles the opposite side of the two heat exchangers, supplying a cold coolant liquid and transporting the 'hot' coolant liquid to the externally located heat rejection unit, with a pump and expansion vessel ensuring the desired flow rate is met and sensors providing the required data for control of the actuators. A three-way valve is again used for temperature regulation with an additional bypass to ensure that the coolant temperature never drops below 0°C, to prevent damage to the pumps. A hydraulic separator is integrated into the system to allow heat transfer between the internal and external cooling fluid loops.

A free cooler mounted on top of the MTF, see Figure 11, dissipates heat from the coolant liquid into the external Antarctic environment.



Figure 11. Mobile Test Facility with roof-mounted free cooler. Credit: DLR

E. Control and Data Handling System

The command and data handling system is responsible for in-situ data acquisition and control within the Mobile Test Facility, for managing all MTF data and for ensuring storage and remote access/control of the MTF from the Neumayer Station III and from User Home Bases located at EDEN ISS project partner premises.

The control and monitoring system of the MTF consists of two PCs connected over an Ethernet switch to the MTF network.

The two CDHS PCs located within the Service Section are the Argus Server PC and the Camera Control PC. These PCs are located in a server rack above the ISPR, as indicated in Figure 4. The Service Section also houses the LabVIEW Control Laptop for ISPR control. A personal laptop may also be used on an as desired basis within the Service Section by the MTF operator (i.e., for non-critical purposes such as accessing MTF procedures, reporting, outreach activities, etc.).

The Argus Server PC, including RAID system, is used to control and monitor all systems inside and outside the MTF except for the ISPR, the safety system, and the camera system, using Argus Titan control software. It can also be used to visualize the control parameters on the connected screens located on one wall of the Service Section, to write or upload new program code to the Argus control system and to download and store Argus control data. The Camera Control PC is dedicated to processing camera images and buffering control data.

The LabVIEW Control Laptop can be used to visualize the control parameters of the ISPR, to write or upload new program code for the ISPR and to download and store ISPR data. It is only connected to the ISPR system in the described situations. Normally the whole ISPR system is controlled by the programmable data acquisition and control board NI-CompactDAQ integrated into the ISPR system using LabVIEW software.

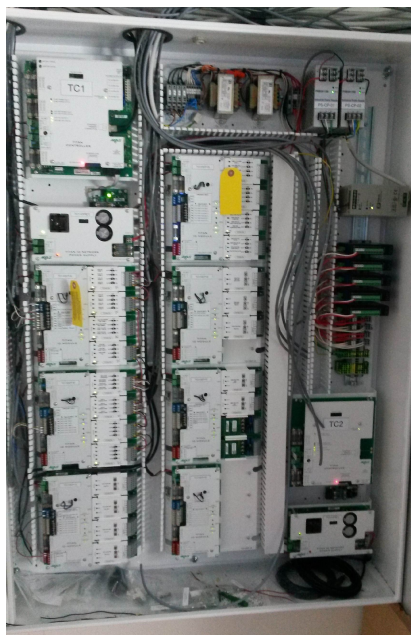


Figure 12: Internal layout of the ARGUS system. Credit: DLR

The Argus System is developed by Argus Controls (Surrey, BC, Canada). It provides a complete hardware and software solution for monitoring and equipment automation purposes. The designed hardware is an essential component for handling the wide range of applications that the Argus system is capable of.

The access point is equipped with a Titan controller and components to facilitate Ethernet connection to the operator PC, external alarm output relays, a battery for emergency backup power, and power supply circuitry for operating the controller and the first segment of the connected I/O communications network. The system is then expanded as needed by simply adding additional controllers connected together by a highly flexible communications network. Wired and wireless controller connection options are available. For maximum safety and reliability, each controller operates autonomously and all controllers are continuously monitored.

Titan controllers are industrial computers designed by Argus. All control programs are executed from the controllers and when accessed from a PC the communication is directly established with the controllers. When the user is not on-line, the Titan controllers automatically operate all of the controlled equipment in accordance with the

dedicated settings and control targets. The total number of sensors connected to the ARGUS system is 121, the total number of actuators is 99 and the total number of cameras is 36.

To accommodate the interfaces for all the sensors and actuators the Argus box will have the dimensions of 1220 x 915 x 204 mm. The Argus main system components will consist of a main access point coupled to a power supply and six relay boards. Also included are nine Modbus modules used to simplify the overall design and reduce the control system footprint. A 24 VAC (75 VA) transformer fed by mains power (220 VAC/50Hz) is located in the Argus panel and provides all the power to the Argus system components within the panel. Argus relays will actuate high power devices through contactors located in the power distribution module. The internal layout of the system can be seen in Figure 12.

Data transfer between the MTF and the NM III is baselined to be conducted in a wireless manner (a cable connection was also considered but not implemented due to reasons of cost and the fact that the MTF is considered a 'crewed' facility, in that operators can visit the facility should communication issues arise). The MTF will include a patch antenna installed on the roof of the facility which communicates through line of sight to a matching antenna installed on NM III. This follows a similar configuration to that presently utilized on the NM III Air Chemistry Laboratory. The CDHS also will contain a WLAN access point which is also connected to the MTF network switch and provides WLAN access to the network/Internet in the whole MTF.

During nominal operation of the MTF and the NM III, a data rate of 100 kbps will be available to the EDEN ISS project for data transfer to the ground station in Europe. For off-nominal situations, such as video teleconferencing, a maximum data rate of 300 kbps will be provided.

Aside from the command and data handling, and the communication components, the CDHS also comprises a safety system to ensure crew safety. This system, consisting of O₂, CO₂ and smoke sensors provides visual and audio cues within the MTF and relevant information is transmitted to the NM III station and the control room in Bremen, Germany.

IV. Mobile Test Facility Operational Characteristics

Based on the designs, and the selected components, mass and power budgets have been established for each of the subsystems. These budgets can be found in Table 3. The mass budgets represent not only those components which are installed in the MTF, but also the spares and consumables which need to be considered for the duration of the Antarctic test campaign. These spares and consumables will be stored within the NM III main station, or in dedicated storage containers which will be provided for the EDEN ISS project. The values also include the components located in the FEG, which have not been discussed within this paper.

The category 'Other/Miscellaneous' covers equipment, spares and consumables related to contamination detection and removal, food safety and quality testing and other non-subsystem related components (e.g. fire extinguisher, disposable gloves and overshoes). The peak power value for this category do not include the components for food safety and quality testing which are accommodated within the main NM III station. Nominal power values are not included as these components are only used in the MTF sporadically.

Note that the mass of the rack structure built into the FEG is included in the FEG container and structure mass, whereas the masses of the rack structures in the Service Section are included in the corresponding subsystem masses. Also note that nominal mode power is the average power consumption over the indicated time period, and takes into account duty cycles.

Table 3: Summary of MTF operational characteristics

Subsystem	Mass	Peak Power	Power day – nominal mode	Power night – nominal mode
Service Section container and structure	7100 kg	-	-	-
FEG container and structure	6400 kg	-	-	-
NDS	849 kg	1498 W	116 W	116 W
AMS	912 kg	5552 W	4584 W	3127 W
TCS	405 kg	2300 W	1900 W	1100 W
IS	352 kg	4769 W	3469 W	0 W
PCDS	533 kg	806 W	698 W	390 W
CDHS	477 kg	2659 W	2560 W	1608 W
ISPR	544 kg	1325 W	957 W	416 W
Other / Misc.	160 kg	88 W	-	-
Overall MTF	17732 kg	18997 W	14284 W	6757 W

V. Summary and next steps

This paper describes the Service Section design of the Mobile Test Facility which was developed as part of the EDEN ISS project. The design reflects the status of the facility at the beginning of the test campaign in Bremen, Germany, which will be the final stage prior to the deployment and operation at the Neumayer III station in the Antarctic.

During the testing phase the performance of the facility will be characterized through dedicated subsystem testing, leakage and acoustic tests as well as crop grow-out experiments to verify the functionality and performance characteristics of the integrated system.

In mid-September 2017 the project staff will shut down the MTF and begin with the preparations for shipment to Antarctica. The preparations include the cleaning of the entire MTF, the disassembly of all externally mounted equipment, the removal of all sensitive equipment from the MTF and its packaging in transport cases, as well as the packaging of all the campaign supplies. In October 2017 a ship departs from the German port of Hamburg in the North of Germany for its journey to Cape Town in South Africa. There the MTF will be transferred onto a South African Antarctic supply vessel for the last leg of the tour to Antarctica where it will arrive around mid-December 2017.

At the same time, an assembly crew consisting of four project staff members will arrive at the Neumayer III station by plane. The assembly crew together with workers from the station operator, the Alfred-Wegener-Institute for Polar and Marine Research (AWI), will lift the two MTF containers onto their platform. Once on the platform, the two containers will be joined together again. All the equipment that has been disassembled for transport will be brought back into the facility and re-installed. Initial system tests will be conducted to ensure that the equipment is working properly. A small remote operations work place will be set up inside the Neumayer III and a data connection will be established between the MTF, the Neumayer III and the main operations center at DLR Bremen.

From the end of February 2018 the MTF will be operated by a single on-site operator, a staff member of DLR Bremen, with the occasional assistance of the other nine overwintering crew members from AWI.

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