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Technical Note

EDEN ISS
Ops Mode and Test Plan

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Ops Mode and Test Plan

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1.0	10/02/2016	A.Ceriello	First Issue
1.1	03/02/2017	A. Ceriello	Par. 7.1: Clarified some roles and responsibilities Par. 8.6: Procedure list updated
1.2	07/06/2107	A.Ceriello	Added the following chapters: Chapt. 7: EDEN ISS Description Chapt. 8. EDEN ISS Operations
1.3	22/09/2017	A.Ceriello	Par.7.4 IPSR Rack: filled with a technical description of the ISPR Rack Par. 8.4.1: Added nitrate Ion meter operations description Par 8.4.3: The chapter has been modified in order to reflect the changes in the safety analysis approach that now foresees the usage of ready to use culture media for microbial contamination assessment (ready to use plates and vials) Par. 8.8.3: Added the description of the following operations: - Stock Solution/Acid/Base Filling - Replacement of the nutrient solution in the NDS tanks Par 11: Added the list of the Labview displays for the ISPR Control Added new chapters: 8.7 ISPR Rack Operations
1.4	24/10/2018		Solved several typo's errors along the entire document Par. 7.3.3: It has been updated with latest information on the AMS configuration. Chapter 8: Paragraphs numbering changed. In particular the paragraph 8.2 content has been included into the paragraph 8.1. The section Power Control system operations has been filled (now par 8.1.3) The section ISPR Maintenance has been filled (now Par. 8.7.5) Chapter 10.6. Procedure List updated. Two separate list are provided, one for the MTF (Par. 10.6.1), the other for the ISPR (par 10.6.2) operations.

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1 Introduction

EDEN ISS is a program funded by the EU having as main goal the development of a greenhouse to be installed in Antarctica at the Neumayer III station to test key technology for a future space greenhouse development. The Antarctica environment has been selected among other sites because its similarity with extraterrestrial outposts, having harsh conditions, and several limitations, including power and number of human operators, and access limitation. From this point of view, EDEN ISS has the objective to test the operation scenario, i.e. the planning of activities, the procedures, and the interaction between on site and remote operators.

2 Purpose

This document describes the operational concept to fulfil the EDEN ISS scientific and technical objectives. It covers the description of the EDEN ISS system and its operations and all the activities and the plan to have the EDEN ISS operations scenario and procedures ready for Antarctic operations.

3 Scope

This document will be used as both an official deliverable and, within the EDEN ISS project team, to address the operative scenario definition and operations products development responsibilities and tasks, the milestones and their link with the other EDEN ISS tasks and milestones. In addition, the document will address the criticalities and their control/resolution plan.

4 Applicable Documents

AD	Document Number	Issue	Date	Title
1		0.1		D 2.5 – Design Report prepared for WP 2.3 – Preliminary Facility Design

5 Reference Document

N/A

6 Acronym List

Acronym	Explanation	Acronym	Explanation
ALARA	As low as reasonably achievable	LOD	Limit of detection
AMS	Air Management System	LUI	Light Use Efficiency
AS	Aero Sekur S.p.A.	MCCS	Major constituents control system
AST	Airbus Defence and Space	MTF	Mobile Test Facility
AWI	Alfred Wegener Institute for Polar and Marine Research	NDS	Nutrient Delivery System
BLSS	Bio-regenerative Life Support Systems	NFT	Nutrient film technique
C&DH	Command and Data Handling	NM-III	Neumayer Station III
CAD	Computer Aided Design	P/L	Payload

CCD	Charge-coupled device	PAR	Photosynthetic Active Radiation
CE	Concurrent engineering	PCA	Principal component analysis
CEA	Controlled Environment Agriculture	PID	Photoionization Detection
		PODF	Payload Operations Data File
CEF	Concurrent Engineering Facility	PSU	Power supply unit
CFD	Computational Fluid Dynamics	QDA	Quality Driving Attributes
CFU	Colony forming units	QMP	Quality Management Plan
CNR	Consiglio Nazionale delle Ricerche	RCD	Residual current device
DLO	Wageningen University & Research	RD	Reference Document
DLR	German Aerospace Center	RH	Relative Humidity
DO	Dissolved oxygen	S/C	Species and cultivars
DoA	Document of Action	S/S	Sub-system
DW	Dry Weight	SMS	Short message service
EC	Electrical Conductivity	SS	Service Section
EDR	European Drawer Rack	SRD	System Requirements Document
EP	Elevated Platform	TAS-I	Thales Alenia Space Italia S.p.A.
ES	EnginSoft S.p.A.	TBC	To Be Confirmed
ESA	European Space Agency	TBD	To Be Determined
ESC	External Storage Container	TCCS	Trace contaminant control system
FEG	Future Exploration Greenhouse	TCP	Transmission Control Protocol
FOV	Field of view	TCS	Thermal control system
H&S	Health and safety	TEC	Thermo-electric cooler
HD	High definition	THC	Temperature and humidity control system
HEPA	High Efficiency Particulate Ar-restance	TM/TC	Telemetry/Telecommand
HI	Harvest Index	TPZ	Telespazio S.p.A.
HS	Heliospectra BA	UDP	User Data Protocol
HW	Hardware	UHB	User Home Base
I/O	Input/output	UIP	Utility Interface Panel
IBAF	Institute of Agro-environmental and Forest Biology	UoG	University of Guelph
IF	Interface	UPS	Uninterruptable power supply
ISPR	International Standard Payload Rack	USOC	User Support and Operations Centre
ISS	International Space Station	VOC	Volatile Organic Compound
LAI	Leaf Area Index	VPN	Virtual private network
LED	Light-emitting diode	WP	Work package
LIT	Limerick Institute of Technology	WS	Work station

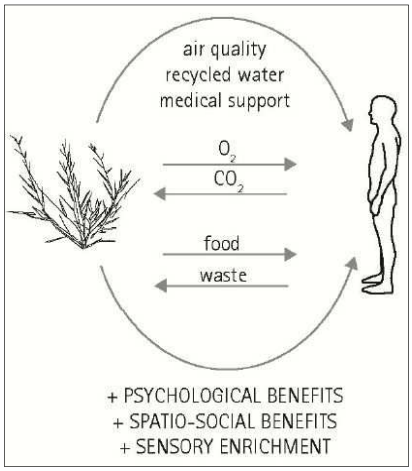
7 EDEN ISS Description

This section provides a description of the EDEN ISS programs, its scientific objectives and the ultimate goal. A description of the EDEN ISS equipment and a description of the operations conduction are given in details.

7.1 EDEN ISS Objectives

Any space exploration plan shall consider the development of a Bio-regenerative Life Support System (BLSS) having the capability to produce on site food and oxygen by recycling human waste, and therefore supporting the need to minimize the resources to be re-supplied from the Earth.

The BLSS is a complex system composed of several compartments having the objective to implement a closed eco-system using an engineering approach. Among the others, the compartments for plant growth is a critical one, since the mission success strongly depends from the capacity to grow plants in an extra-terrestrial environment.



Cultivation in closed environments is challenging and several key technologies (i.e. light, nutrient and cultivation recipes) for reliable high yield production are still being developed and are far from being space qualified.

Greenhouse operations is another critical item to be taken into account. In fact the operations are not only covering the system operations, like for example opening and closing a valve of the irrigation system, and/or changing the light intensity of a lamp. An astronaut will be called to manage plant growth techniques and shall be familiar with activities like plants seeding, training, pruning etc. But even more important, the astronaut shall be able in an early identification of disease signals. From this perspective, the implementation of health monitoring system, processes and procedures is very important for an early detection of disease symptom, as well as the definition of remote support from the plants experts for the definition of medical treatments. Therefore, the possibility to implement a remote support, in terms of a network of distributed expertise's, has to be considered, with the possibility to distribute data coming from the greenhouse to such centers.

In addition, the necessity that the food produced in an extraterrestrial greenhouse shall be safe and healthy for human consumption has to be considered, with the identification of tools, processes and procedures for food quality and safety analysis, and sanitization technique.

Lastly, a greenhouse shall be a safe environment for plants and for the astronauts. That define the need for the implementation of microbial analysis methodologies and, if necessary, ambient sanitization procedures.

EDEN ISS project has therefore the objective to develop a test platform for the implementation and validation of what described above in the light of a future deployment in on-orbit/transient facilities or Moon/Mars habitats.

This test platform will also accommodate an ISS payload like system for cultivation of tall plants in a reduced volume, with the objective to prepare an intermediate step for mid-term experimentation on board of ISS.

Finally, as usual for all the space programs, EDEN ISS will also serve to exploit terrestrial application of the findings along the project.

7.2 EDEN ISS Mobile Test Facility (MTF)

The EDEN ISS Mobile Test Facility (MTF) is being designed as a test bed for key plant growth technologies and operations in view of future space experiment, having in addition the objective to provide fresh produce for overwintering crews at the Neumayer III (NM-III) Antarctic station.

The MTF will consist of two 20 foot high cube containers, which will be placed on top of an external platform (fig. 1 and fig.2) located approximately 200 m south from NM-III (fig.3)

Figure 1: Illustrative impression of the EDEN ISS Mobile Test Facility.

Figure 2: the MTF installed at the DLR during the AIT phase

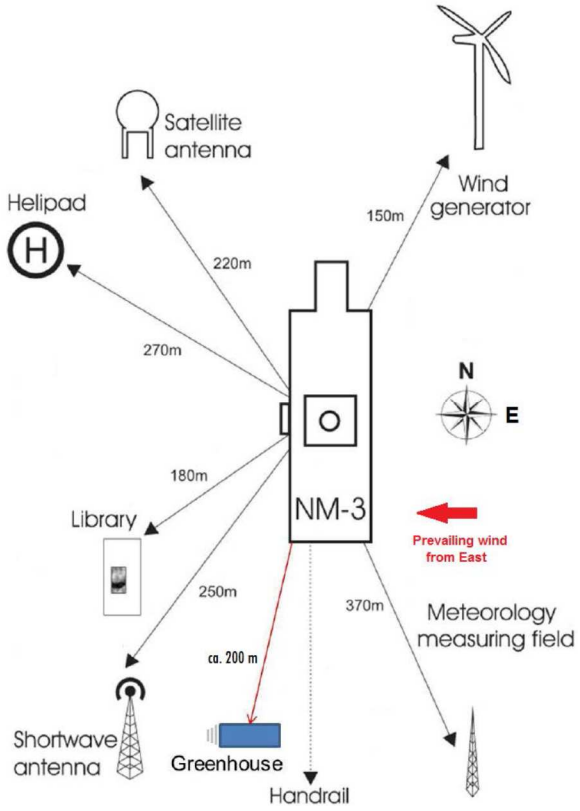


Figure 3: Location of the MTF ('Greenhouse') with respect to Neumayer Station III ('NM-3') and other associated station infrastructure.

The MTF is subdivided into three distinct sections (as illustrated in Figure 4):

- Cold porch/airlock: a small room providing storage and a small air buffer to limit the entry of cold air when the main access door of the facility is utilized.
- Service Section: is the main working room that houses all the EDEN ISS Subsystems and the computers to control them. In addition, it houses ISPR Rack plant growth demonstrator.
- Future Exploration Greenhouse (FEG): the main plant growth area of the MTF, including multilevel plant growth racks operating in a precisely controlled environment.

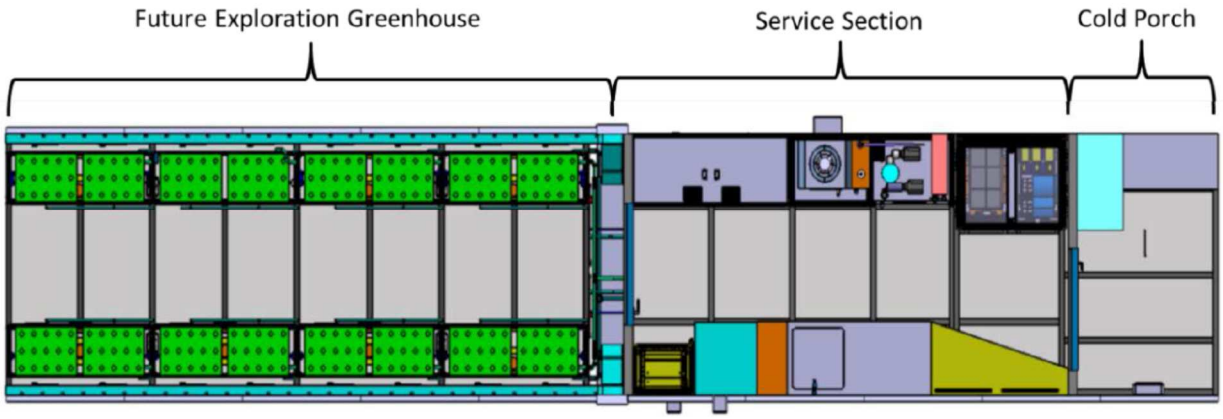


Figure 4: Top-view of the Mobile Test Facility's internal configuration.

The Airlock and the Service Section are contained in one single container (hereinafter named the 'Service Section Container') while the other container (the FEG Container) is containing the only FEG. The two containers are connected each other, nevertheless a separation wall for internal division of the containers, and to permit a distinct environment to be maintained in the FEG, is installed within the FEG container. The door

separating the Service Section and FEG is of transparent construction to better permit NM-III crewmembers to remain outside FEG while still observing the plants. Three other doors are present in the structure, one is separating the cold porch from the Service Sections the other two are respectively the nominal and emergency exit door.

One big window is placed on one side of the Service Section allowing an external view toward the NMII base.

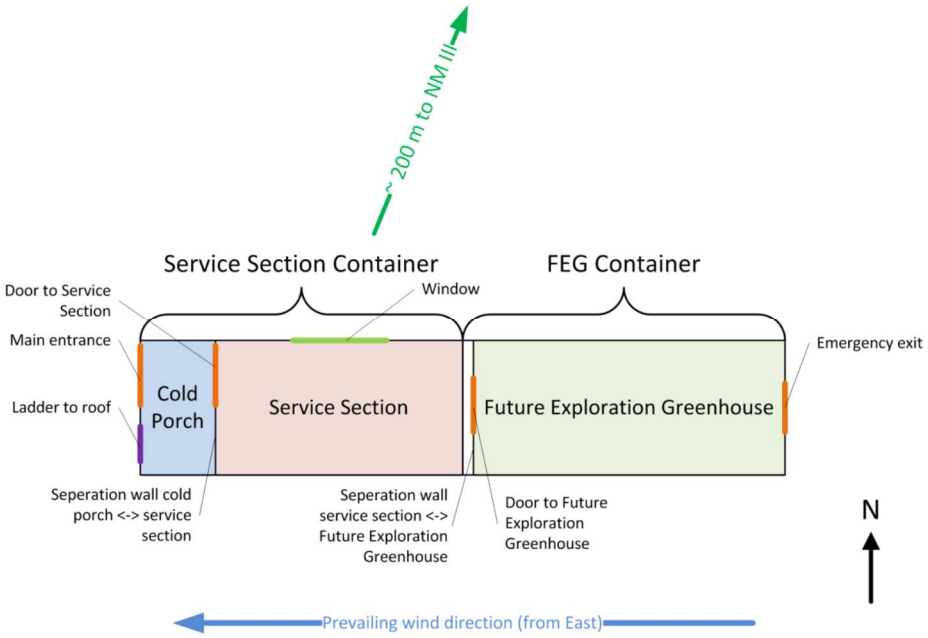


Figure 5: Orientation and main elements of the MTF.

The total internal length of the MTF is 11840 mm, of which 5770 mm is reserved for the FEG, 5770 mm is reserved for the Service Section and the remaining 300 mm is space between the two sections, which is needed for interfaces, such as ducting, piping and cabling.

The MTF utilizes power generated by NM-III and provided via a heavy gauge electrical cable buried under the snow/ice.

The operator and other crewmembers accessing the MTF will for the most part travel on foot from the NM-III to the MTF. The handrail running south from the station will be extended in the direction of the MTF and can be used in instances of inclement weather. NM-III skidoos and sleds can be used for the transport of larger materials or fresh/waste water to and from the facility.

7.2.1 Service Section Container

The main part of the Service Section Container is the Service Section (fig.6 and fig. 7) that hosts the main subsystems:

- Air Management System (AMS)
- Thermal Control System (TCS)
- Nutrient Delivery System (NDS),
- Power Control and Distribution System (PC&DS)
- Command and Data Handling System, (CD&HS)
- General Operator Workspace including a workbench, a sink, a tool storage area as well as displays for the several computers deployed for the MTF management and control.

The Service Section is also equipped with an external patch antenna for the communication between the MTF and the NMIII station.

The Cold Porch allows for the operator preparation before the entrance in the Service Section, as for example dismiss the polar suit, take the necessary tools etc. The Cold porch also houses the water tanks beneath the floor (for both fresh and waste water) (fig. 8)

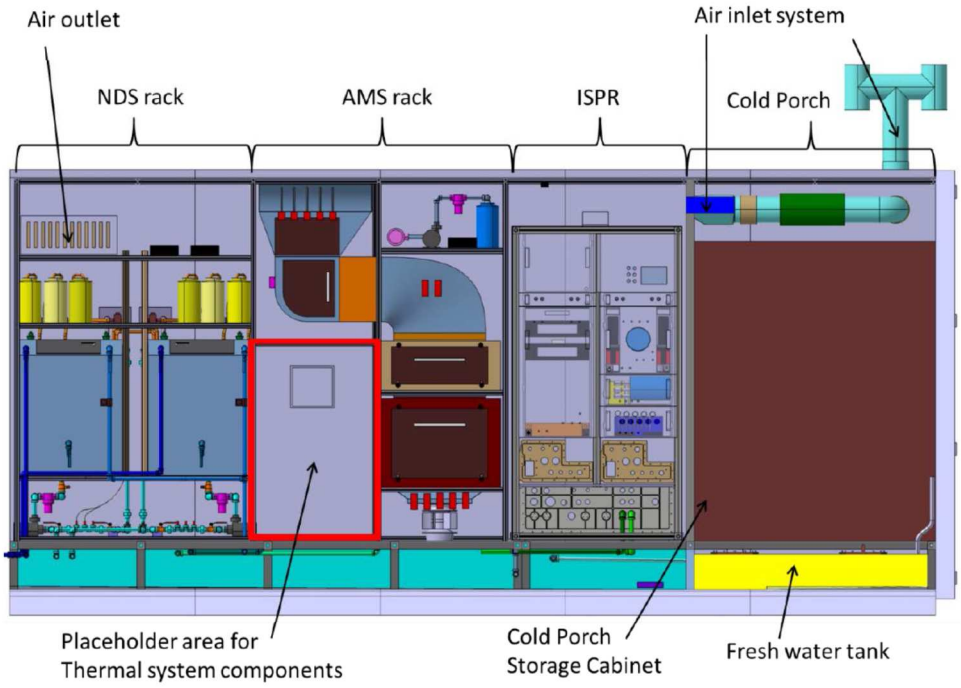


Figure 6: Service Section cut view – South side.

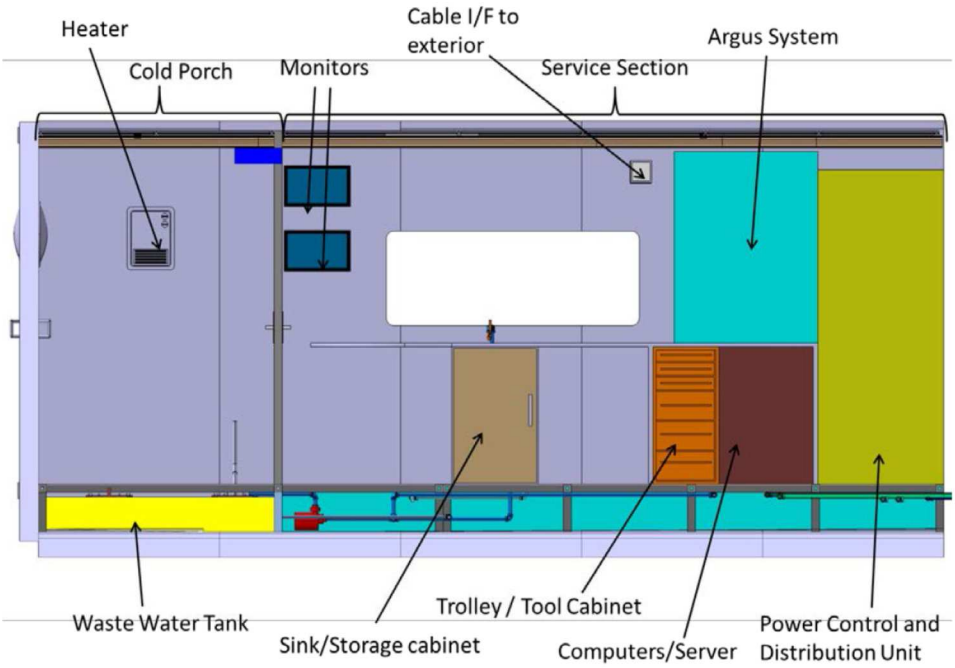


Figure 7: Service Section cut view – North side.

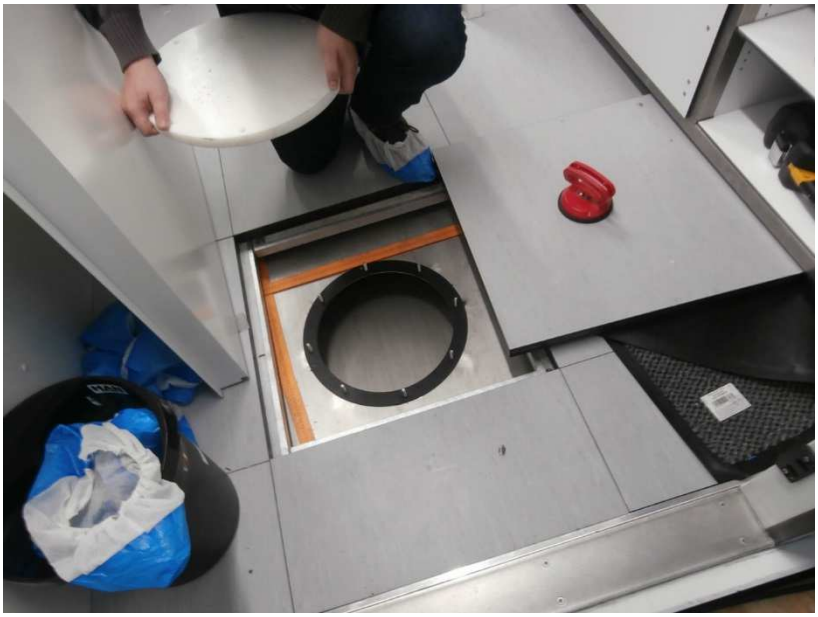


Figure 8: Fresh Water Tank in the Cold Porch

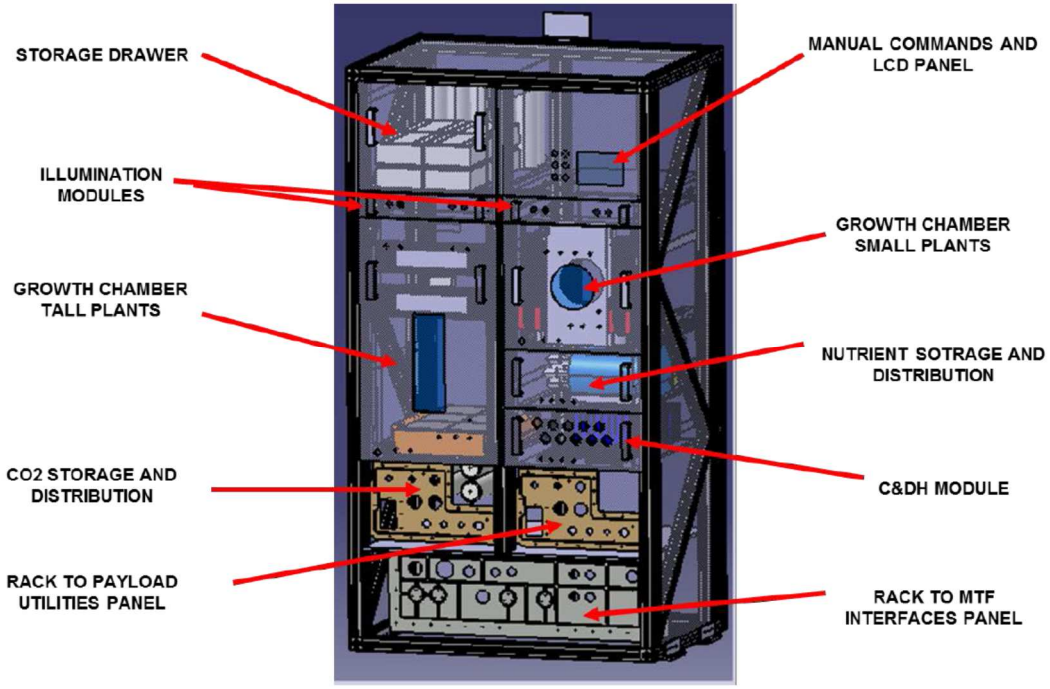


Figure 9: EDEN ISS ISPR system concept as precursor of ISS European Drawer rack EDR II payload.

The so-called **ISPR demonstrator rack** (fig. 9) is also located in the Service Section. It is a small-scale green-house implemented to test key technologies to be implemented on payloads for ISS experiments. For that reason, the ISPR Rack has been designed to mimic full-rack form factor ISS International standard payload racks (ISPR), with the objective to deploy the key part of it as payload in the ISS European Drawer Rack (EDR) II.

7.2.2 Future Exploration Greenhouse (FEG)

The Future Exploration Greenhouse is the MTF compartment devoted to plants cultivation. It is composed of a number of multilevel growth systems in which plants are grown under LED light and are irrigated in a combination aeroponic-nutrient film technique type system. Plants are grown within commercial off the shelf 60 cm x 40 cm Euro boxes modified to incorporate aeroponic tubing and crop-customized tray covers to optimize plant spacing to the extent possible. The FEG houses eight distinct plant growth racks, each capable of receiving its own nutrient solution. A camera system is integrated in the growth system as Plant Health Monitoring system providing the capability to acquire both top view and lateral images.

Figure 10 presents the general construction of the FEG plant racks with the identification of the various elements of the multilevel racks. With respect to that, it is important to know how the environmental parameters are controlled, i.e. what are the capabilities of the greenhouse. For example, light intensity and composition can be controlled separately for each unit, but that it is not true for all the other parameters, like the temperature that in principle is the same in the entire chamber. The table 1 provides a summary of what can be controlled and for what.

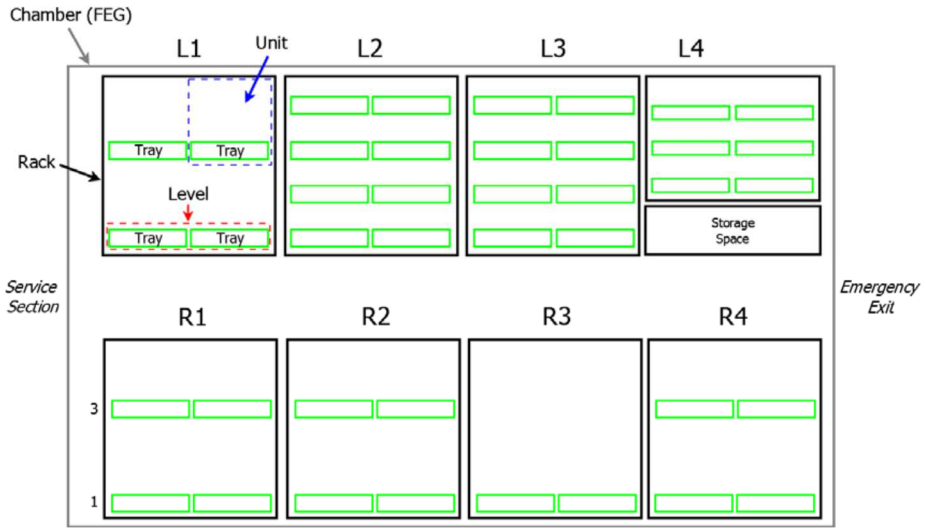


Figure 10: Overview of FEG plant growth unit elements and topology of FEG plant grow racks.

Table 1: Controllable environmental parameter depending on plant growth unit element within the FEG.

Element	Controllable Parameter	Description
Chamber (FEG)	Atmospheric environment	The entire chamber, and thus all elements composed within have the same atmospheric environment. Though to the extent possible the team will utilize the fact that the FEG will have zones of differing temperature (e.g., warmer near top), differing humidity and possibly differing CO_2 partial pressures etc. to position crops to obtain more optimized conditions.
Rack	Nutrient solution	The entire rack, and thus all elements composed within have the same nutrient solution. Note that there are two different nutrient solution options within the MTF and a rack can be provided with either of the two solutions. Each rack is fed with one pump and thus irrigation frequency is defined on the rack level.
Unit	Light quality and quantity	As each unit (and thus tray) includes its own devoted LED panel, permits the control of light quality and quantity at the unit level. LED panels include individual control of the four selected LED types and thus permit a high level of illumination control. Nevertheless, some stray light from the neighbouring panels will occur.
Tray	Structure	Each tray is its own distinct 60 cm x 40 cm root compartment and employs its own lid, each of which can be customized to a given crop (e.g., root zone depth, root support structure, plant spacing).

7.2.3 Service Section/FEG Containers Interfaces

The two containers, which make up the MTF, are connected together and sealed to separate the internal environment from the harsh Antarctic conditions. The containers are mounted on twist locks, welded to the platform, and fixed together with four bridge clamps, joining the four pairs of adjacent cornerstones.
The gap between the containers is closed with a rubber seal, which is covered by metal sheets on the outside. On the inside, the seal is covered by insulation material, which in turn is covered by metal sheets. Floor panels are used to cover the gap between the two container floor structures. Figure 11 shows how the two containers making up the Air Chemistry Observatory are being connected in the Antarctic. The MTF has a similar interface as this observatory.

Figure11: Container interface of the Air Chemistry Observatory

7.2.4 Neumayer III Interfaces and Services

Neumayer Station III (fig. 12) is located on the Ekström Ice Shelf in Antarctica's Atka Bay. NM-III was constructed during the 2007 – 2009 summer seasons. The two-story, above ground portion of the station is situated on an elevated platform 68 m long by 24 m wide and provides 2118 m_2 of living and working area. The elevated platform is constructed on 16 hydraulic struts that allow the station to be raised to accommodate snow accumulation, thereby extending the station life expectancy. The bulk of NM-III resupply occurs once a year by ship. Each December the AWI research vessel Polarstern (fig. 12) delivers resupply and research equipment from Bremerhaven, Germany, via Cape Town, South Africa, to the coast of Antarctica near the Atka Bay. The supplies are then moved over the ice with Pistenbullys (tracked vehicles) to the station. Smaller items such as crew exchanges and certain foodstuffs are provided through air service to the station via Novo Airbase or Troll whose ice runways serve as hubs for stations and field sites within Dronning Maud Land. NM-III is crewed year-round. In summer (Dec to Feb), typically 40 to 50 people work at the station, whereas only nine crew members are present during the winter period (Mar to Nov).

Figure 12: (Left) Neumayer Station III. (Right) Polarstern.

The MTF operator and other overwintering crewmembers participating in the operation of the MTF will conduct a number of MTF duties such as monitoring, nutrient solution preparation, sample processing, etc. For that reason, within NM-III, a space within the ca. 25 m^2 NM-III multipurpose laboratory (Figure 13) will be allocated to EDEN ISS activities as well as a control center setup in this same general space. The left hand side (when entering the room) of the laboratory has been planned by AWI for EDEN ISS activities. This includes the sink area as illustrated in the right hand side image of Figure 13. Following the departure of the summer field season crewmembers, an even larger space will be available to EDEN ISS operations.

Figure 13: Two views of the NM-III multipurpose laboratory.

As one of the primary goals of the EDEN ISS project is to demonstrate a remote operations capability, NMIII will provide also a satellite connection for the EDEN ISS remote control. Data from the MTF will be transmitted over a wireless link to NM-III and subsequently over the NM-III satellite connection to the EDEN ISS Ground Network. The present satellite connection provides NM-III with a bandwidth of 300 kbps. A bandwidth of 100 kbps has initially been used as a design to reference for EDEN ISS data transfer limitations. It should be noted that AWI is presently in discussion to increase the overall station bandwidth to 1 Mbps and that this could be implemented before the deployment of the MTF.

NM-III Interfaces and Influences on MTF Operations

The design of the MTF is influenced by the local Antarctic environment but also, by its interaction with the NM-III station itself. The MTF will utilize a number of resources from the station and in a number of instances, because the MTF is located externally to the station (unlike a number of other Antarctic plant production systems), this interface is further complicated. A general depiction of a number of the MTF to NM-III interactions are illustrated in Figure 14.

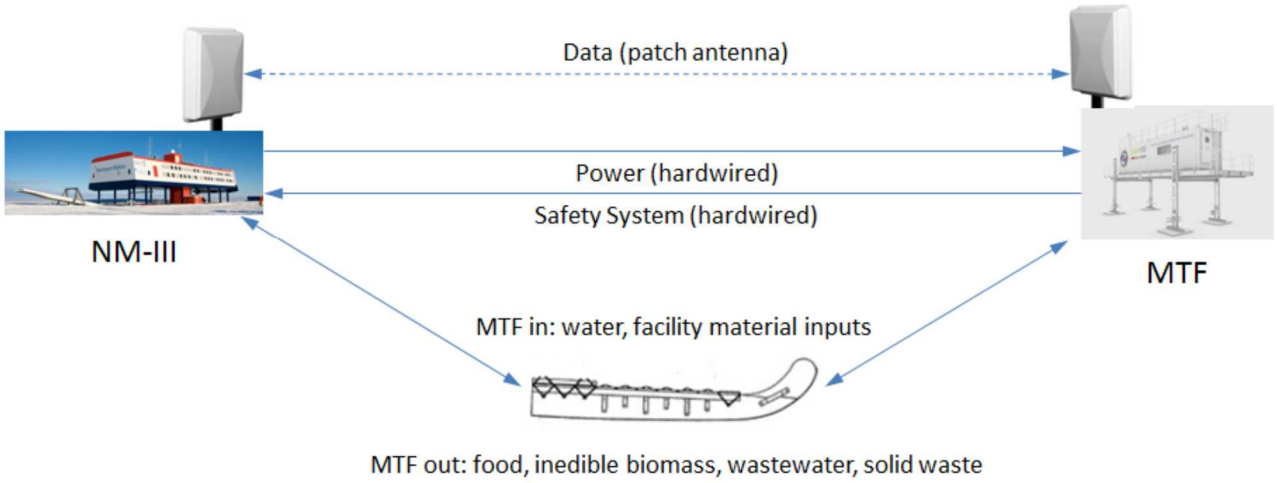


Figure 14: Neumayer Station III to MTF interfaces.

As seen from Figure 14, cables will be installed for the provision of power to the MTF and for the reception of some MTF safety signals within NM-III. A heavy gauge, electrical cable will be run between NM-III and the MTF and provide power to the MTF from the station's electrical power generation system (diesel generators and a wind turbine). The cable will be initially buried approximately 50 cm under the snow/ice surface and will be installed in the same fashion as that depicted in Figure 15 when a similar cable was installed for the Air Chemistry Laboratory. Due to the large amount of annual snow accumulation in the NM-III vicinity (70-120 cm annually), a reasonable amount of slack will be left on the cable before connection to the main MTF power box.

The bulk of MTF data and commands sent from Europe or directly from the NM-III control center will be through a wireless link between the NM-III and MTF. Other consumables, hardware, generated biomass and waste will be hand carried or transported in sealed boxes or tanks on a sled.

Figure 15: Heavy gauge electrical cable being laid for the NM-III Air Chemistry Laboratory. A similar cable and procedure is baselined for the MTF.

7.3 Subsystem Description

The MTF subsystems have been designed to ensure that all the conditions for plants cultivation and for human operators presence inside it are satisfied. Their detailed description it is out of the scope of this document and are available in the dedicated S/S design document. Nevertheless, in this document an overview is provided.

7.3.1 Power Control and Distribution System

A power and distribution system will distribute the power provided by NMIII to all the MTF subsystems. The MTF has an installed power demand of around 44.6 kW and additional 2 kW for the non-permanently installed TransMADDS as shown in table Table 2. The system has been designed to fulfill these requirements. On the other hand, it not expected that the system will work at its maximum limit. In fact, the average power demand of the MTF calculated over one year is around 11.5 kW with a different power demand during the imposed day-night cycle.

Table 2: EDEN ISS S/S Power Demand

	Installed power	Phase No.
CDH	1.0 kW	1
General	4.0 kW	1
Ops and Coms	1.8 kW	1
AMS	7.0 kW	2
NDS	1.5 kW	1
Thermal	3.0 kW	2
ILS	25.4 kW	3
ISPR	0.9 kW	1
TOTAL	**44.6 kW**	

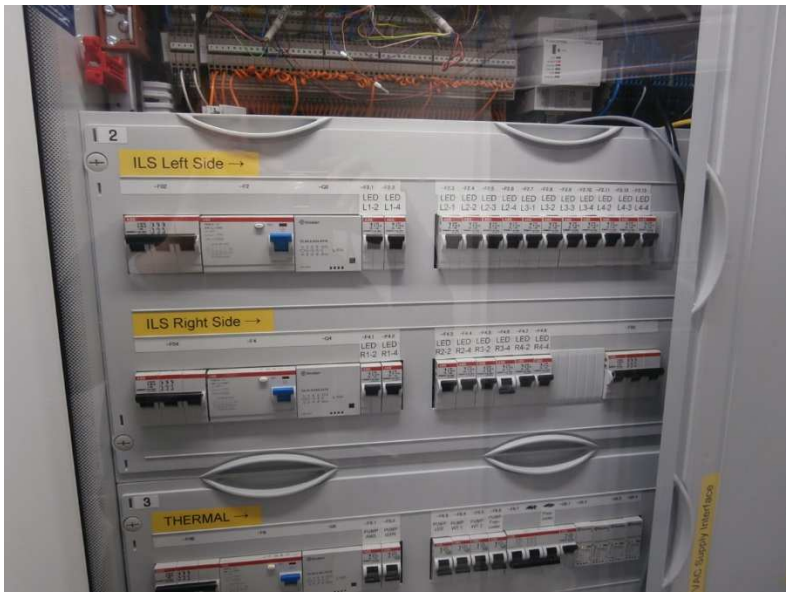


Fig. 16: PC&D System Interface Panel

The PC&D system consists of the main power box, cable channels for power and data cables, the power cables, and the internal and external lighting.

The main power box is the heart of the MTF. It splits the incoming three-phase line from Neumayer into separate lines for the different subsystems and components. The primary cable channels, as illustrated as red lines in fig.17, are attached to the ceiling of the MTF and run along the walls of the service section and in the corridor of the FEG. In addition to the primary channels under the ceiling there are also secondary channels which run vertically at strategic points to direct cables to equipment located e.g. within the different level of the FEG. Most of the power cables are for 230 VAC even if there are also a number of components running at 24 VDC. Both cables typology are certified for wet rooms.

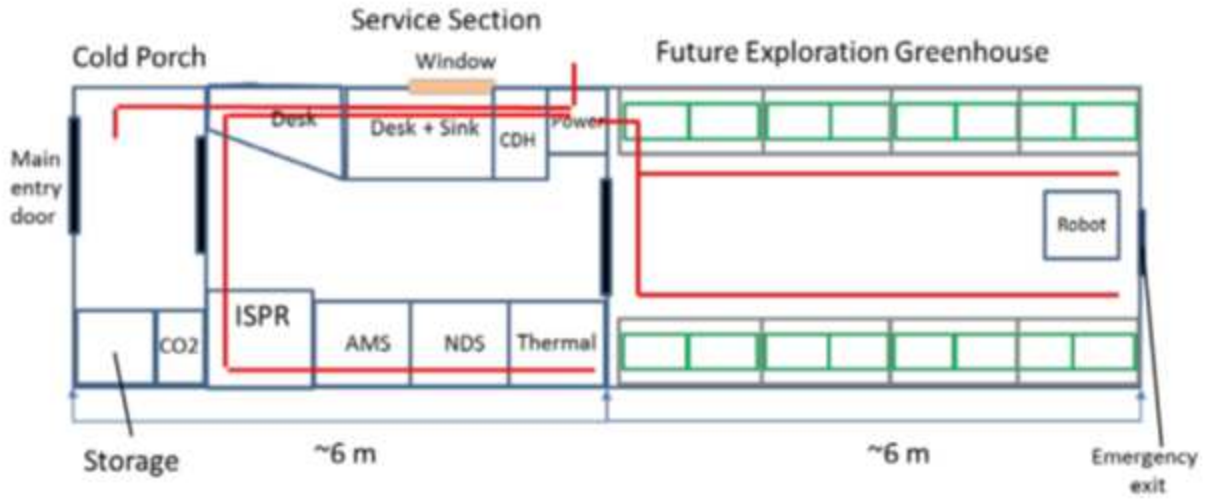


Fig. 17: Power distribution (red lines)

The PC&D system includes a system to measure the overall energy consumption of the MTF as well as the consumption of each subsystem and selected components. Such system has been implemented to get a better insight in the total electrical energy required to produce food in a closed environment for the identification of optimization potential with respect to energy efficiency.
Finally, a backup power supply (or uninterruptable power supply (UPS)) has been implemented within the MTF with the objective to overcome potential power shortages and voltage fluctuations and to avoid the uncontrolled shutdown of the command and data handling system and the communication between the MTF and Neumayer. An EATON Evolution S 1750 UPS with an additional extension battery has been implemented with a capacity to run at 70 % of the maximum load for 36 minutes. Table 3 shows the equipment that will be connected to the UPS.

Table 3: List of equipment that needs to be buffered by the UPS.

Equipment	Amount	Power demand
Argus Server PC	1	350 W
Mobile Platform and Camera Control PC	1	350 W
Access point	1	4 W
Argus System	15	300 W
Safety systems	1	60 W
Switch	1	28 W
Patch antenna	1	8 W
VoIP phone	1	10W
	TOTAL	**1110 W**

7.3.2 Thermal Control System

The thermal control system is aimed at the provision of chilled water to the cooling systems of the Air Management System and the LED lamps, and to the ISPR Rack, to dissipate the heat they generate during operations. It is composed of two internal cooling loops for heat collection and one external loop for heat dissipation to the Antarctica Environment. The first internal loop is interfacing the AMS system, the second the LED Panels and the ISPR Rack as follow

- Cooling Loop 1: AMS
    - 6.6 kW heat load
    - 1.1 m³/h max. volume flow
    - 8°C inlet temperature
    - 15.2°C return temperature
- Cooling loop 2: ISPR & LEDs
    - 4.3 kW heat load (1.3/3.0 kW)
    - 0.63 m³/h max. volume flow (0.19/0.44)
    - 20°C inlet temperature
    - 25.9°C return temperature

The cooling process is very simple and is done oft he following steps:

1. The coolant fluid of the cooling internal loop (water-Tyfocor mixture) collect the heat generated by the AMS, LED panels and the ISPR Rack
2. The collected heat is transported to the a liquid-liquid heat exchanger
3. Within the heat exchanger the heat is transferred from the internal loop to the liquid of the external loop (water-Tyfoxit mixture)
4. The heat is transported to the cooler mounted on the MTF roof and dissipated in the Antarctica environment.

The following fig.18 and fig.19 show the position of the Thermal Control System within the Service Section and its layout.

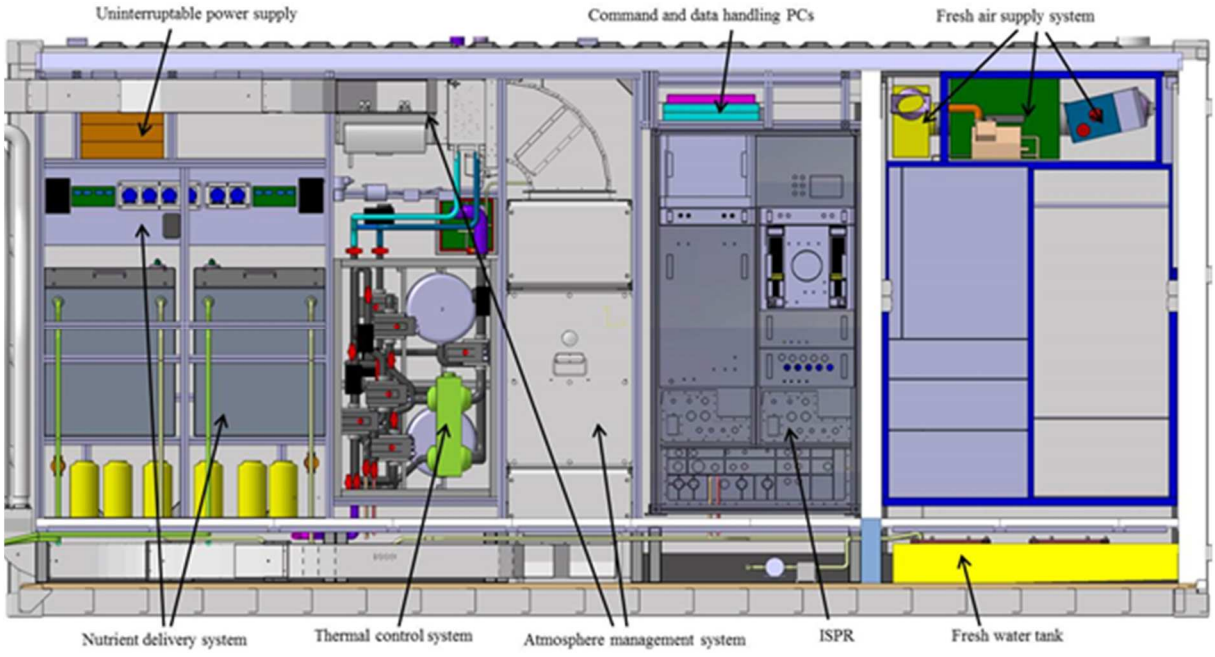


Figure 18: Thermal Control System position within the Service Section

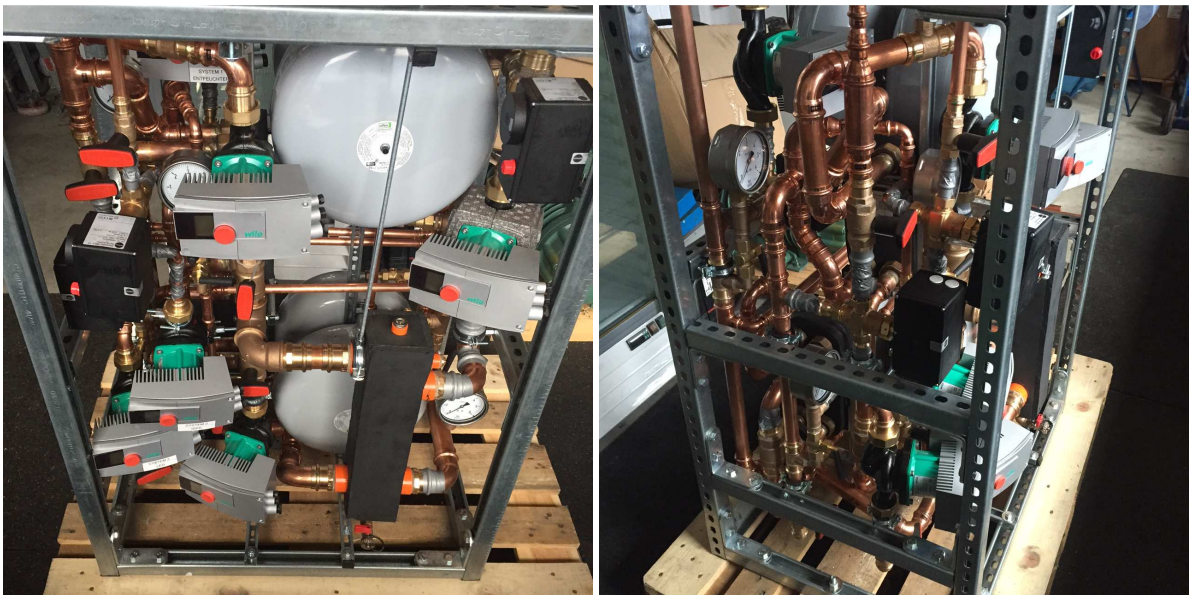


Figure 19: The Thermal Control System

Figure 20: The External Chiller

7.3.3 Air Management System

The Air Management System has the objective to maintain the environmental condition in both the Service Section and in the FEG within the defined range and taking into account the harsh external environmental conditions, which for the Antarctica Site are defined as follow:

External environmental parameters:

- Summer: +5°C, max. temperature, with RH of 92% ref.
- Winter: -50°C, min. temperature, humidity negligible
- Solar radiation: min. 0 W/m2 max. 960 W/m2

Of course, different conditions have to be set and maintained in the SS and in the FEG, being the first compartment devoted to human operations and the second to plant growth.

While the environmental conditions within the cold porch are not actively controlled, aside from a heater which maintains the temperature above a set minimum, for the Service Section the target is defined as per the following table:

	Day	Night
Temperature	21 degC	18 degC
Relative Humidity	25-30 %	N/A

Within the SS, the environmental conditions are controlled through the inflow and outflow of air. A humidifier located within the SS enables control of the relative humidity within the enclosed area.

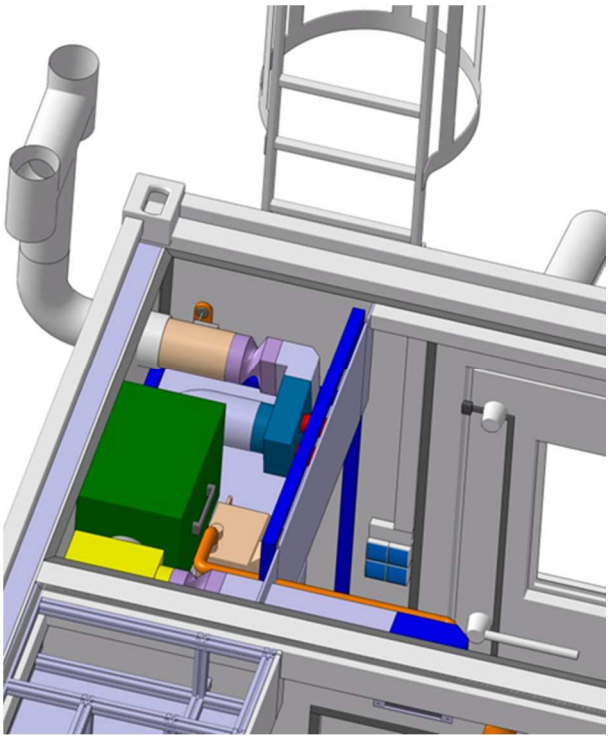


Figure 21: Service Section air inlet

Figure 21 shows the current configurations of the air inlet. The air inlet has an H-shaped cowl, to prevent snow from entering the facility. The air enters the air duct and is first heated by a heater, before passing through a filter system. A fan ensures sufficient pressure head to overcome the losses in the system. Finally, the air enters the Service Section through the plenum and louver, with the opening located just above the door separating the cold porch and the Service Section.

A humidifier injects water vapour into the air ducts, after the fan, to maintain the relative humidity in the Service Section within the desired range.

An air outlet was initially foreseen in the design, but ultimately discarded. Because the volume flow rate for the fresh air supply is relatively low it was not deemed necessary to have a dedicated outlet. Air will leave the facility upon crew entering or exiting the facility and it is expected that this will be sufficient to prevent air pressure from rising too high, thereby preventing fresh air from entering the facility and cooling the Service Section.

The air Inlet is controlled over a thermo-regulator. Once the temperature within the Service Section reaches a specific set point, the controllable valves is instructed to open. The fans are powered on and operated at a pre-determined set point. Similarly, the heater for the air inlet are powered to heat the incoming air to 5°C, with the actual setting dependent on the external temperature. The system will run until the temperature inside the Service Section drops down to the minimum temperature set point. Circulation fans within the SS will run continuously, mixing the air, ensuring that the conditions at the sensors are representative of the entire Service Section conditions. Once the air Inlet have shut down and the air has been mixed, the humidifier will be activated and will run until the relative humidity sensor indicates the desired value has been reached.

At night, if the Service Section is cooling down, the heater in the Service Section is activated to maintain the internal temperature. Nevertheless the fresh air supply is reduced to a minimum value, since external air is not required for cooling.

As far as the FEG is concerned, the AMS ensures, in addition to the control of Temperature and Relative Humidity, the control of several other parameters according the requirements listed below:

Crop parameters:

- Production area 12,3 m²
- Transpiration rate: Day, 160 g/m²h (total: 2050 g/h – all trays, fully mature crops) Night, 385 g/h
- CO_2requirements – 370 g/day (actual calculated)
- pp$Ethylene_{max}$ = 15 ppb (continuous), 100 ppb (trans. – 30 min)
- Canopy level wind speed: from 0,2m/s to 0,4 m/sec preferable (long term) max wind speed 5 m/s for few hours min. wind speed 0.01 m/s (note that an initial target of 0,2 m/s was utilized but the requirement was eased based on initial CFD simulation results).

FEG internal parameters:

- Tnom = 22°C, Tmax = 30°C for one day with light; Tmax = 34°C , Tmin = 8°C for 2 days
- RH = 70±5%, Rhmin = 45% for 12 hours
- Rhmax = 96% for 4 hours (assumed the distribution throughout the FEG is perfect)
- ppCO_2 = 650 ppm, ppCO_2 max = 1500 ppm (24 hours) (germination phase & cucumber is lim-iting)
- Leakage: 500% total FEG volumes per day (note that this considers leakage from the FEG – not the MTF overall).
- LED power: 4,5 kW

That is done by means of several AMS components as depicted in the following block diagram (fig. 22).

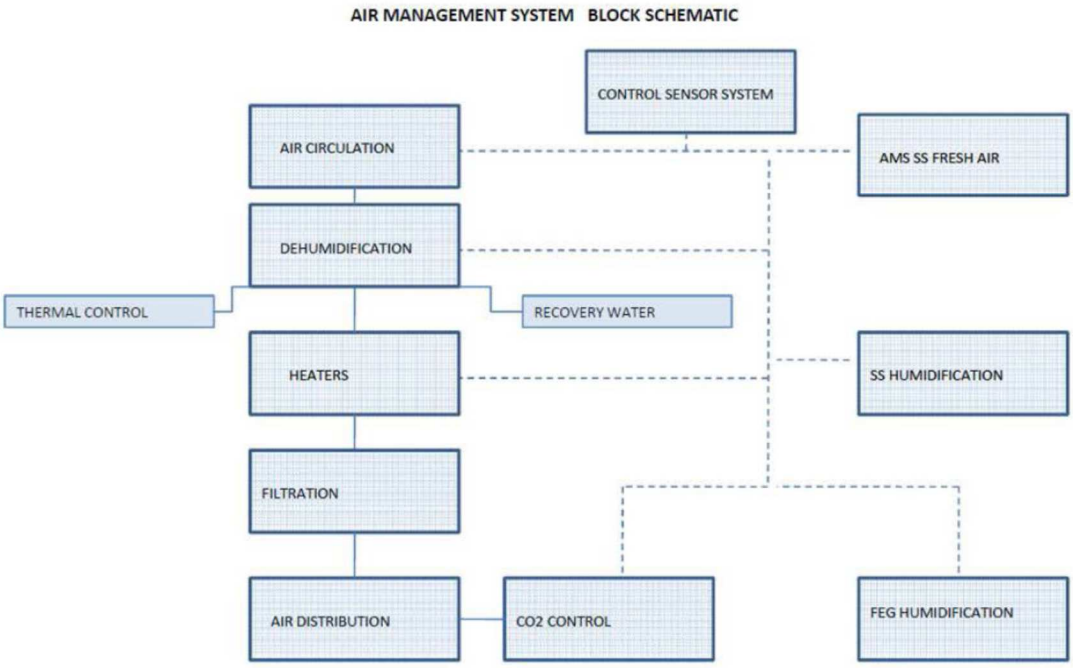


Fig. 22: AMS Block Diagram

Starting from the top, the first block is the **Air Circulation**: this block provides the required amount of air flow rate at the system. Main components are two fans, one before the filtration system to compensate mainly the pressure drop in this system; the second installed after the filters on the pressure side of the ducts, to compensate the pressure drop of all the duct distribution system.

The **Dehumidification** block provides the recovery of the water transpired by the plants: this water, transformed in Humidity, passes through a Heat Exchanger air–liquid where is created a cold wall: the cooled liquid is supplied by the Thermal System. The temperature is set in order to reach the air dew point and to obtain the water condensation. The subsystem **Recovery Water** is composed by an UV-C lamp submerged directly in the condensed water tank, a pump and a mechanical filter. After that, the water is sent to the fresh water tank.

The **Heater** block is composed by a heater elements installed in a mechanical duct. After being cooled, the air has to be reheated at the proper temperature, passing through the heaters.

The **Filtration** block is composed by the UV-C lamp, the prefilter with absolute filter HEPA H14 and the VOC scrubber. Aim of this functional block is to guarantee the state of the air recirculating in close circuit in the greenhouse. The UV-C lamp is installed before the heat exchanger but from the functional side it belongs however at this block.

The **Air Distribution** block contains all the components dedicated to the proper air distribution from the AMS unit to each single point of the FEG section: this distribution is realized with main ducts, which give and aspire the air between the Service Section and the FEG. Into the FEG are installed 8 ducts giving air on the crop, each of them with a constant flow valve and distribution louvers.

The **Block Humidification** is composed by 2/3 Humidifiers, installed in different points of the FEG section to guarantee the proper humidity value, variable in function of the growing degree of the crop.

The **CO_2 System** is the system dedicated to the maintaining of proper value of CO_2: it is composed by cylinders of CO_2, valves and piping.

The **Control System Sensors** groups all the sensors foreseen in the AMS: all signals coming from those sensors will be sent at a central Command and Data Handling Unit, to realize the complete control of the system: Temperature, Relative Humidity, CO_2 level, O_2 level, Air flow rate, mechanical filter pressure drop.

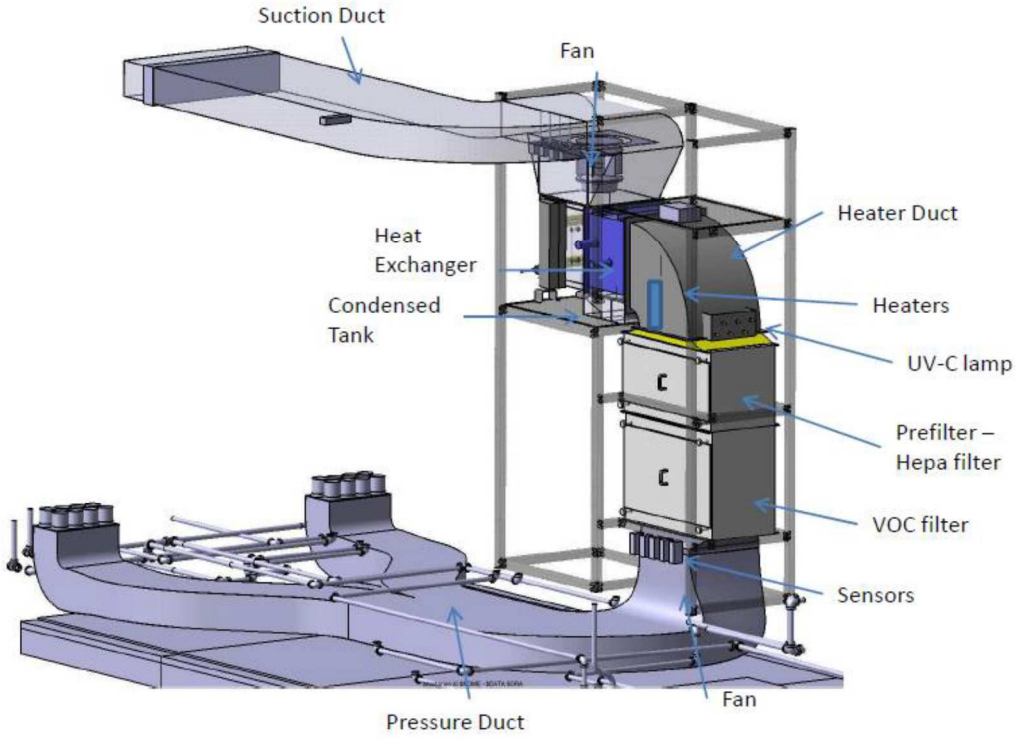


Fig. 23: AMS layout for FEG

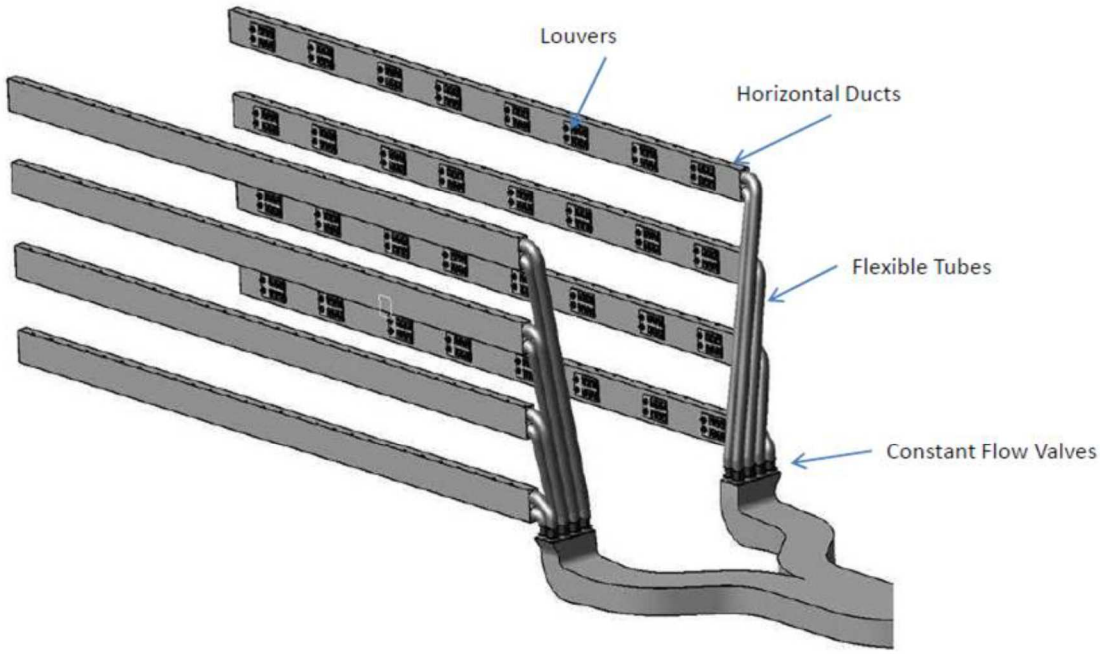


Fig. 24: AMS Ducts layout

7.3.4 LED Lighting System

The lighting system of both the FEG and the ISPR Rack is based on water-cooled LED panels (fig. 25)developed by Heliospectra with the following features:

- Dimensions: 210 x 372 x 86 mm.
- Control: IP based control via Ethernet.
- Thermal Control: Water cooled (fig. 26)
- Power Demand: 600 W peak.
- Spectral quality: The light spectrum will be produced by 450, 660 and 735 nm LEDs along with a broad-band white 5700K LED. The resulting spectrum will have the following composition:
    - 15% blue (400-500 nm)
    - 10% green (500-600 nm)
    - 75% red (600-700 nm)
    - 2% far-red (700-750 nm)
- Dimming – Each wavelength is independently dimmable.
- IP rating – IP65 or better.
- Design – The housing is made of aluminum with tracks compatible with Item system fasteners.
- Intra-canopy light – In addition to the WX intracanopy lighting will be used to provide more light when plants in chamber R3 (tallest rack) are small.

Fig.25: Heliospectra LED Panel

Figure 26: Led Panel Water Cooling Line

Each of the lights has an internal HTTP end point (a webserver). The web server publishes both a User Interface (webpage) but also allows machine-to-machine control. The C&DH system will be the main User Interface for the control system and it will use the HTTP interface of the lamps.
Initially each lamp is given a static IP address. The reason for a static address is to reduce the need for a separate router. The physical position of each lamp can also be associated with the IP address. Regardless of the addressing scheme there are standard tools that can be used to assign IP addresses during the AIT phase. The IP address for the lights need to be stored in the C&DH system.

7.3.5 Nutrient Delivery System

The overall NDS design is based on an existing hydroponic concept developed by DLR that is a hybridization of 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 (Figure 27) located within the Service Section contains two 250 litre nutrient solution tanks and primary variable speed mixing/delivery pumps. Sensors include pH, DO, temperature, water level and water flow, while manual system disinfection can be achieved with an integrated ozonation system. Stock nutrient reservoirs, acid/base control solutions and dosing pumps are contained above the main tanks, and delivery pumps are controlled by the C&DH System. 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). 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.

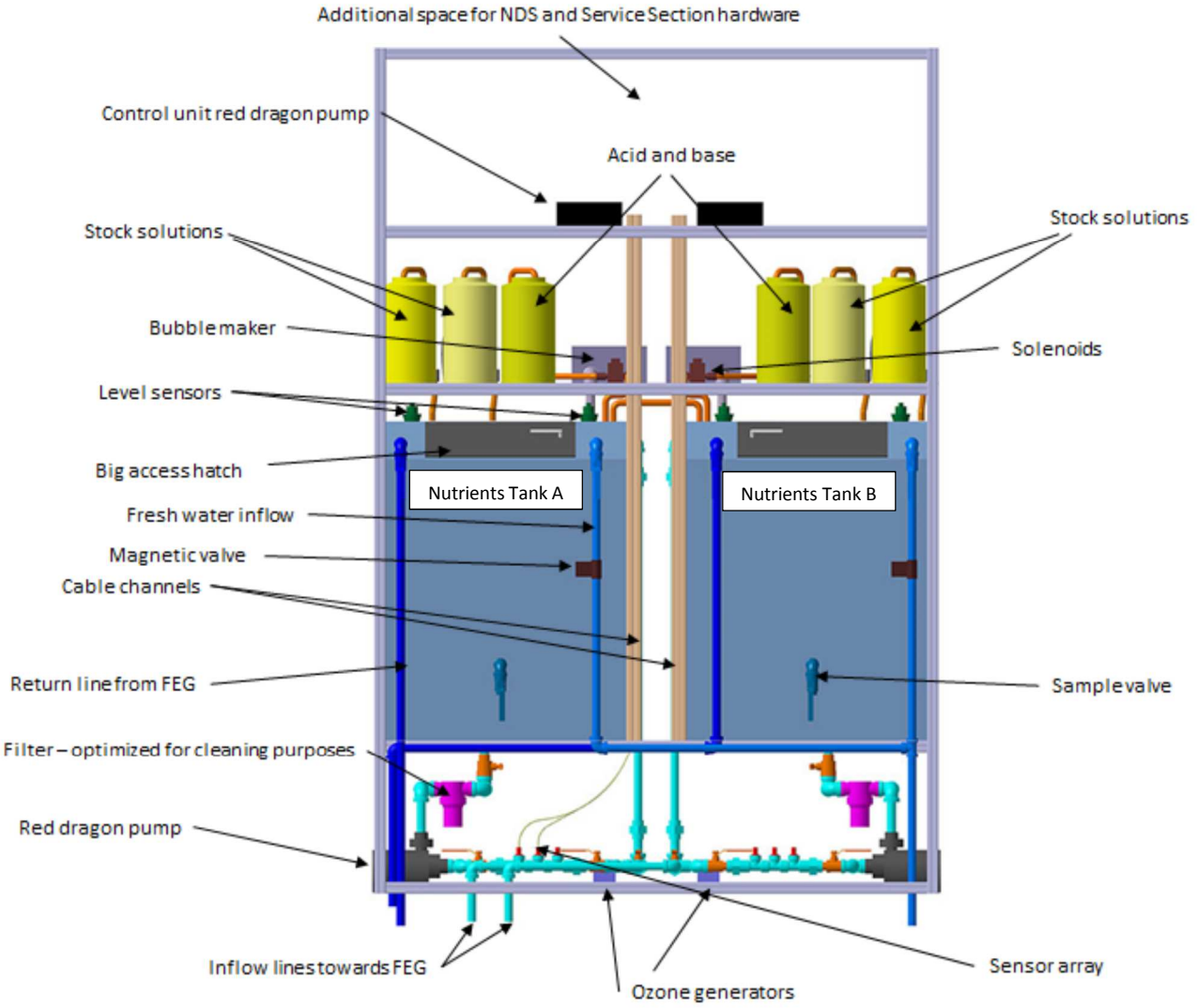


Figure 27: Front view of the main NDS rack components within the Service Section.

The main NDS rack feeds the growing 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 fog/mist nozzles. Growing racks consist of either 8 grow trays (short plants e.g. lettuce, basil, etc.), four grow trays (medium plants, e.g. tomato) or two grow

trays (tall plants e.g. cucumber). An additional 6 tray short plant rack is also available for seedling establishment or additional planting space for short-stature plants. Each stack 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 (fig.28). 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 (fig. 29) 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 will be recovered by the condenser located in the Atmosphere Management System rack in the Service Section. Recovered water will be directed to the fresh water tank located in the floor of the airlock. Additional water from the fresh water tank will be injected into the nutrient tanks as required to maintain a predetermined water level or for nutrient composition control. A cooling loop will be included in the nutrient tank design, but will only be implemented if excessive temperatures are encountered in the nutrient feed.

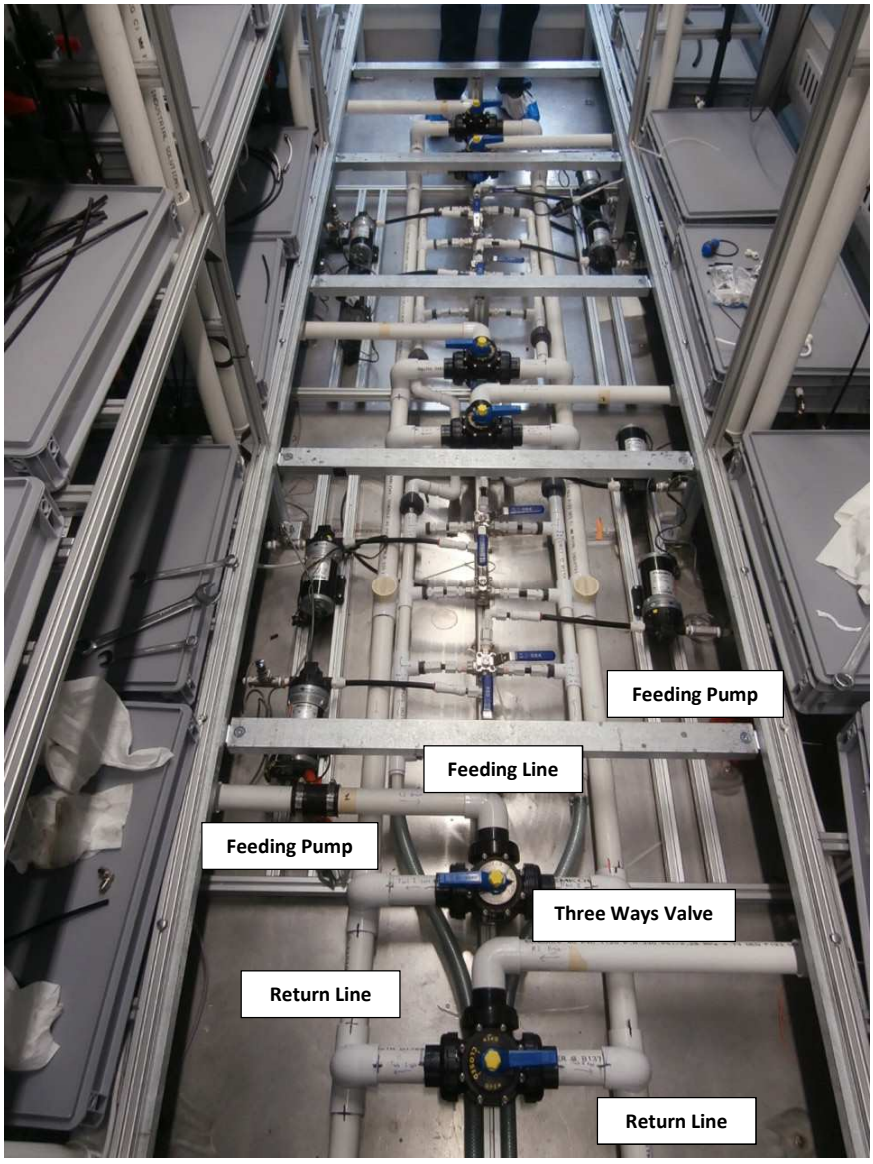


Figure 28: Under-floor layout of the NDS supply and return piping.

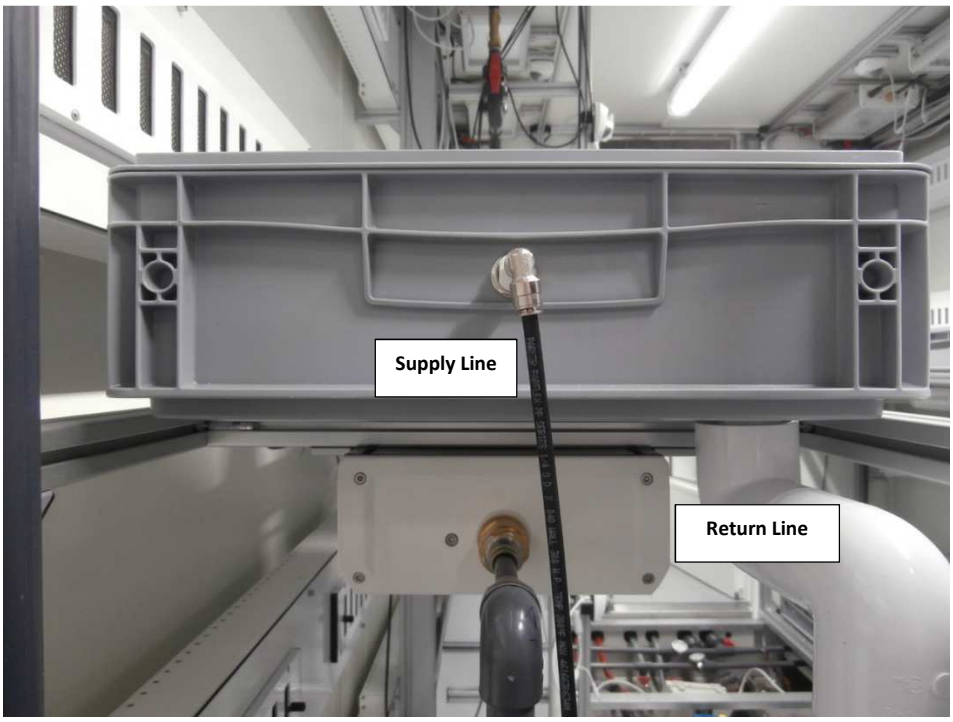


Figure 29: NDS supply and return piping at drawer level

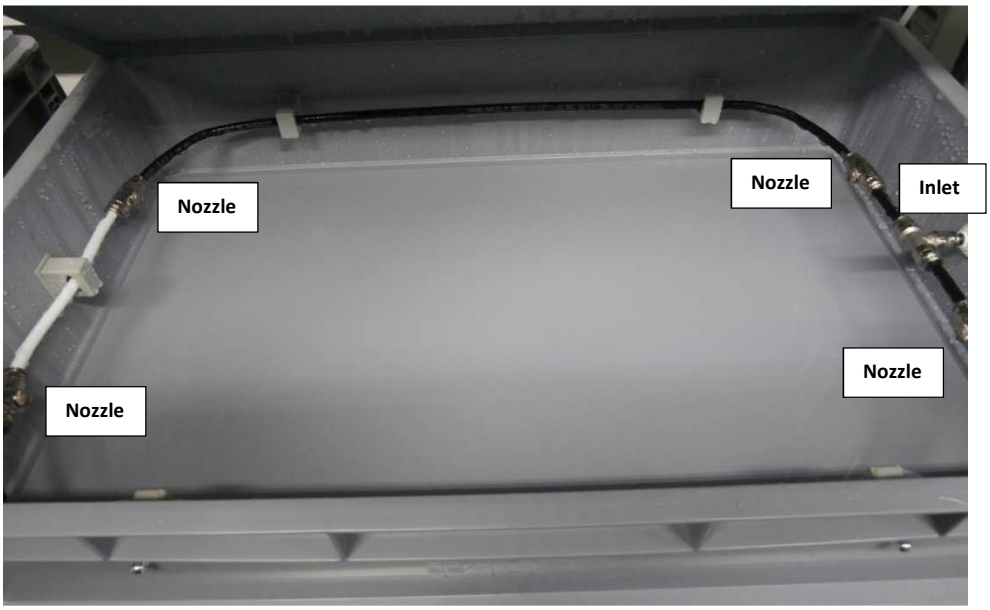


Fig. 30: Water/Nutrient Solution Provision to the Root Zone

7.3.6 Plant Health Monitoring System

One of the key points of the FEG performance monitoring is the plant health monitoring, and most of all the early detection of plant disease and the subsequent activation of corrective actions. For that reason, a plant monitoring system is foreseen with the objective of collecting information suitable for analysis by a knowledge system (either local or remote) to assess and advise prophylactic measures to the local operator. The system relies on several components:

- Top view images by a fixed system of visual cameras one for each/two trays
- Lateral view images by a fixed system of visual camera's one for each rack.
- One HD-video camera modified for multispectral imaging
- An automatic system for daily images acquisition, local storage and forwarding to the European sites.

A total of 40 HIKVISION DS-2CD2542F-I camera's have been acquired for the project, they are used as follow:

- 17 are mounted on the ceiling of each rack level (with the exclusion of the nursery), pointing down-ward towards two trays for top view imaging (fig. 31)
- 8 are mounted on the ceiling of each nursery level (two per level, one for each tray), pointing downward towards the trays, for top view imaging
- 8 are mounted along the corridor, on the rack structure pointing at the opposite rack for lateral view imaging (Fig. 31)
- 4 are used as internal ambient monitoring
- 3 have to be considered as spare items.

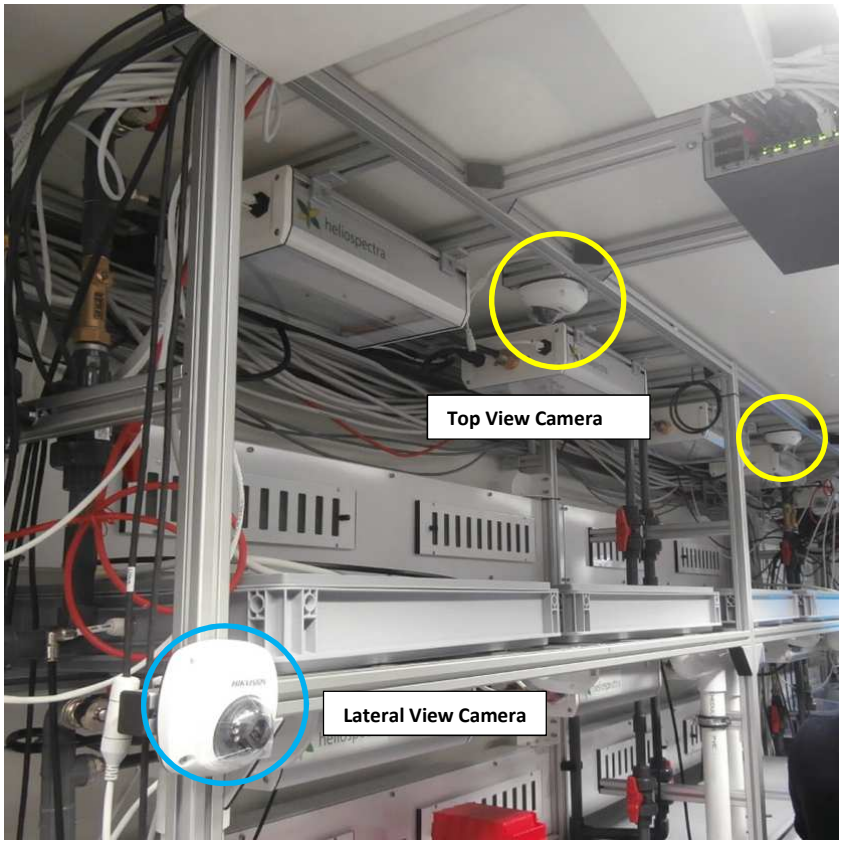


Fig. 31: Top and Later View Camera's

In addition other two HIKVISION camera's have been acquired for the exterior videomonitoring purpose, in particular the DS-2CD4026FWDA. This camera is equipped with the multifocal lens HV3816D-8MPIR and housed in a box equipped with heaters (the VIDEOTEC HPV42K2A160) to increase its operability to – 50 degC, the lower temperature that can be experienced at the Antarctica site were the EDEN ISS MTF will be installed.

The cameras are connected to the MTF network via Ethernet switches (fig.32) located in the FEG and the Service Section. Two FUJITSU Server PRIMERGY RX1330 M2 computers are available at the Antarctica site for the camera's system configuration and control, one located in the MTF, the other in the NMIII station. They have the same characteristics and features and will be configured in similar way in order that one is the backup of the other, providing the capability to replace a failed PC with minor or no modification.
Both have installed the same SW for the camera control, and will allow the camera system configuration and control, i.e. the operator can do the same operations independently of the location. But only one computer will be used for images storage, even if both are equipped with the same RAID system. This computer is the one located in the NMIII station.

Fig. 32: Camera's and LED Lamps Server

7.3.7 Command & Data Handling System

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

The command and data handling system of the MTF is subdivided into:

- Control and monitoring system,
- Camera system,
- Safety system.

The **CDHS** consists of two PCs connected over an Ethernet switch to the MTF network. This local network is connected to the Neumayer III Ethernet network via two patch antennas, one installed outside the MTF facing NM-III and one installed outside NM-III facing the MTF. The total number of sensors connected to the command and data handling system is 215, the total number of actuators is 145 and the total number of cameras is 41.

The command and data handling PCs are installed in a 19'' rack system box with the dimensions of 600 x 600 x 900 mm located in the Service Section above the ISPR Rack (fig. 33). A 24 ports network switch and the UPS of the Power Control System are also installed in this box.

Fig.33: CDHS Computers installed above the ISPR Rack

Fig.34: Computers Screens

The two CDHS PCs located within the Service Section include the **Argus Server PC** and the **Camera Control PC**. 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 the ISPR, the safety system, the camera system and the mobile platform using Argus Titan control software. It can also be used to visualize the control parameters on the connected screen located on one wall of the Service Section (Figure 34), to write or upload new program code to the Argus control system and to download and store Argus control data.

The **Camera Control PC**, including RAID system, has various tasks including:

- Processing of images from camera system using dedicated software,
- Buffering of control data (but no controlling task by Argus or LabVIEW).

The MTF operations will be mainly managed through the **Argus Control System**. The system is comprised of a central controller and separate I/O (input/output) modules that interface the actuators (controlled equipment) and sensors within the system.

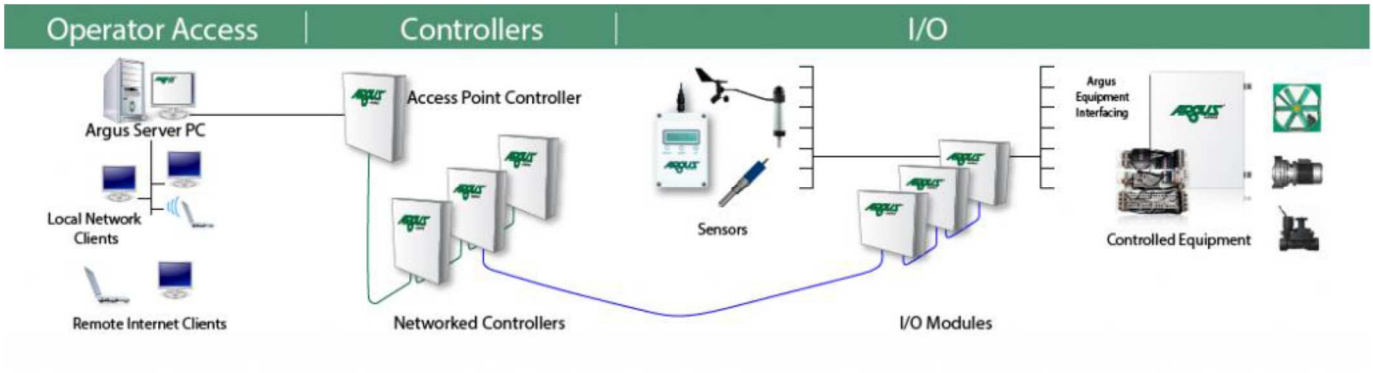


Fig. 35: Argus Network

The Argus System will be used to configure and control both the FEG and the environmental conditions in the Service Section. That will be done automatically and in accordance with the dedicated settings by the Titan controller, that represents the core of the Argus system. The user can in any case change the settings or define different control strategy accessing the Titan controller by means of the Argus Server PC, or via any other PC connected with this last one and equipped with a Argus Client SW. This feature will be implemented in the EDEN ISS network.

Table 4: Sensors and actuators connected to the Argus control system.

Argus			
Subsystem	Location	Amount	Sum
NDS	FEG.NDS	10	33
	SES.NDS	22	
	CPO.NDS	1	
	FEG.NDS	8	23
	SES.NDS	15	
ILS	FEG.ILS	42	42
	FEG.ILS	42	42
TCS	EXT.TCS	5	38
	SES.TCS	25	
	FEG.TCS	8	
	SES.TCS	12	14
	FEG.TCS	2	
PDS	SES.PDS	3	3
AMS Cold Porch	CPO.AMS	4	4
AMS FEG	FEG.AMS	6	20
	SES.AMS	14	
	FEG.AMS	9	15
	SES.AMS	6	
AMS Service Section	SES.AMS	5	5
	SES.AMS	3	3
	Sensors:		145
	Actuators:		97

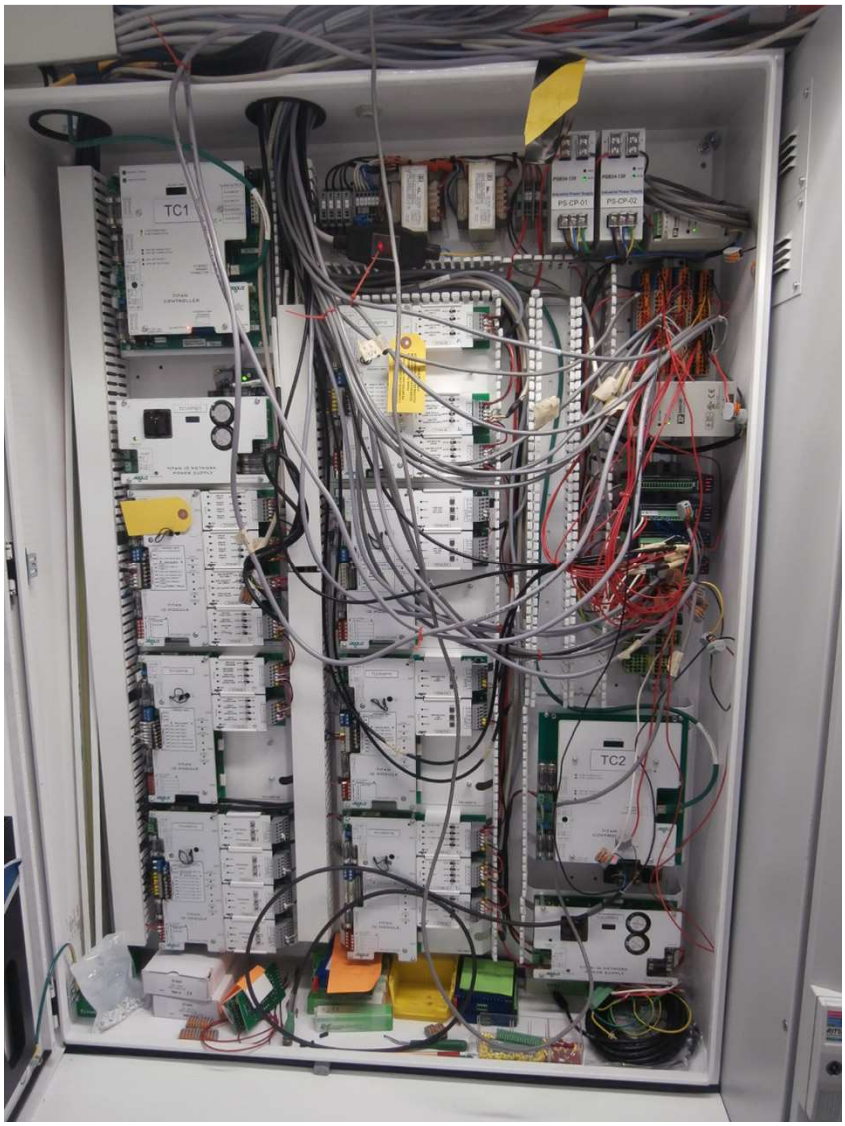


Fig.36: Argus System Implemented in EDEN ISS

The camera configuration is done by means the HIKVISION provided SW (SADP tool and/or the iVMS-4200). By means of this SW the camera will be configured in terms of both system and network parameters. On the contrary the automatic acquisition and distribution of the images will be done by the following scripts developed ad hoc by TPZ:

- hikvision.py
- camera_snapshot_robot.py
- camera_ftp_robot.py

The camera_snapshot_robot.py is the SW application for picture acquisition, while the camera_ftp_robot.py is taking care of the file transfer to the remote sites. These SW applications require the definition of several parameters, like for example the camera network parameters, the storage path, the destination path etc. These parameters are defined in the hikvision.py SW application that therefore is a sort of subroutine of the other two applications.
In addition, to automize the storage path creation, the acquisition of the images and their distribution to the remote site two batch files have been developed:

- edeniss_mkdir.bat

- edeniss_scheduler.bat

The HIKVISION SW will be installed on both the MTF and NMIII Camera PC's allowing the configuration from both the consoles. On the other hand the scripts for the automatic acquisition and distribution will be running on the NMII PC only.

The camera system, including the switches and the computers for camera control are part of the EDEN ISS network that includes of course all the other systems and components for the EDEN ISS operations.

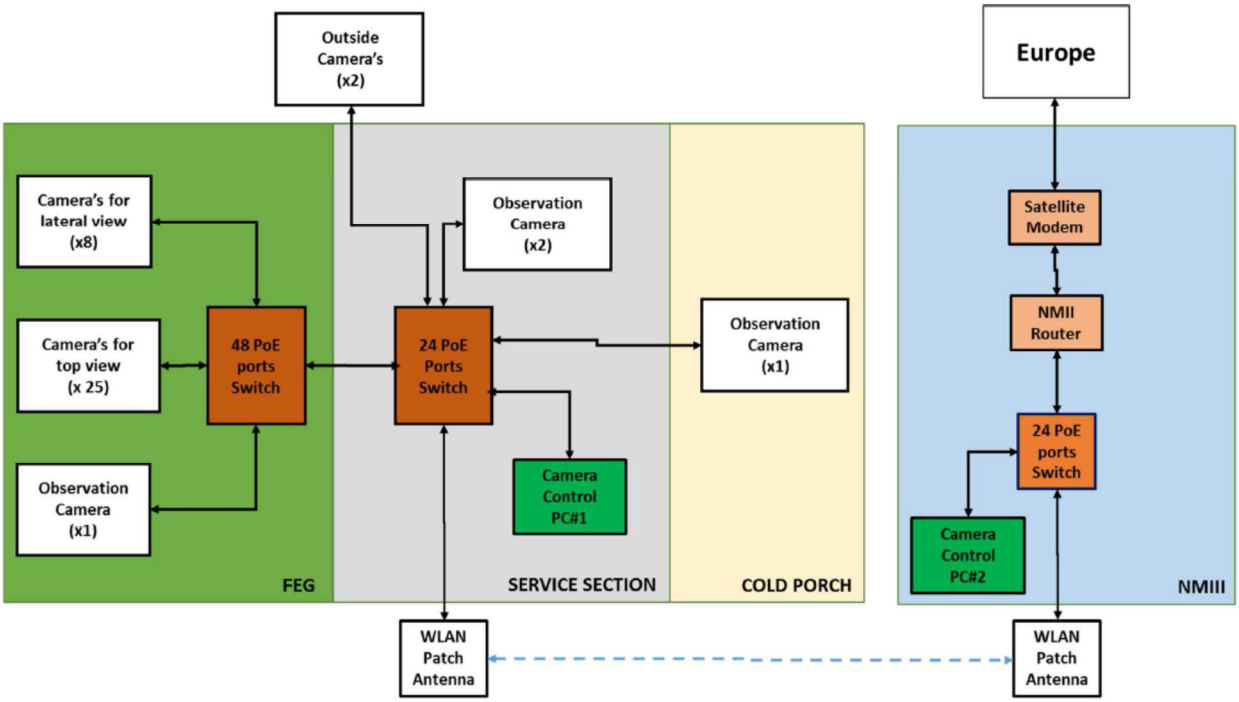


Figure. 37: Camera Network

7.4 ISPR Rack

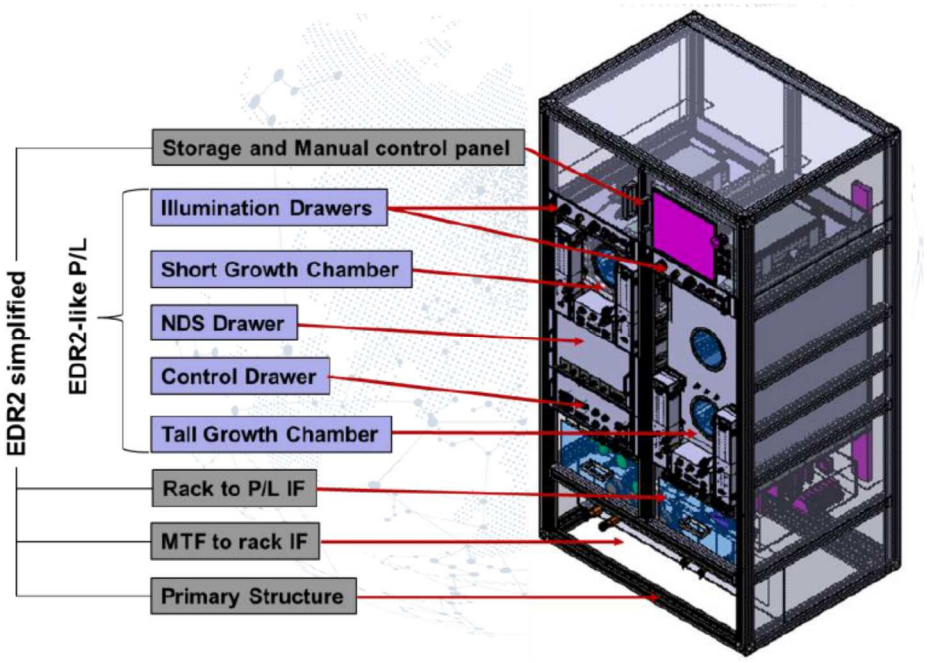


Figure 38: The ISPR Rack Concept

In order to target a feasible ISS operations scenario, the ISPR Rack has been conceived in the shape and functionalities of the European Drawer Rack, a multipurpose facility developed by ESA and hosted in Columbus, having the capability to accommodate different experiments in terms of space availability (can accommodate drawers of different size), and in terms of availibility of thermal and avionic (both power and data) resources and interfaces.

Following this concept the design has concerned not only the realization of the experiment equipment but also of the structure and such interfaces that in principle will be already available when the entire plant growth equipment will be installed on board.
The Fig. 38 clearly shows the concept. The As-built ISPR Rack is composed of two main parts:

- The **EDR Simplified part** that is replacing the EDR functionalities (in principle could be considered as a sort of Ground Support Equipment or an Engineering model) and provides the required interfaces and resources
    - MTF to ISPR Interfaces
    - ISPR to PL Interfaces
    - Drawer Accommodation Volume
    - Storage Volume
    - Panel for manual monitoring and control
- The **EDR like P/L**, that is providing all the specific functionalities necessary to conduct a plant growth experiment. This P/L is composed of several modules as follow:
    - Power, Command and Data Handling (Control) Module
    - Nutrient Storage and Distribution Module
    - Growth Chamber Modules (1 for short plants, 1 for taller plants), including each chamber dedicated Air Management Systems, Root Modules and Crop Shoot-Zone Volumes
    - Illumination Modules (one for each growth chamber)

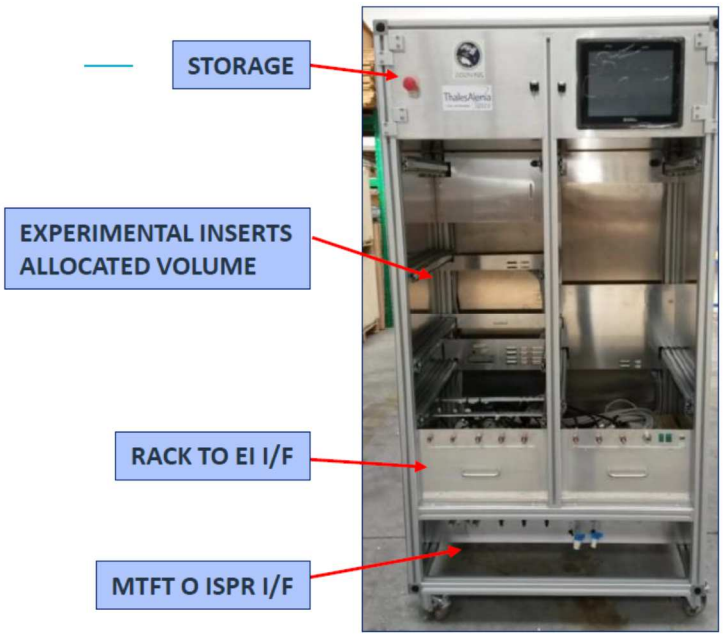


Figure 39: EDR simplified part

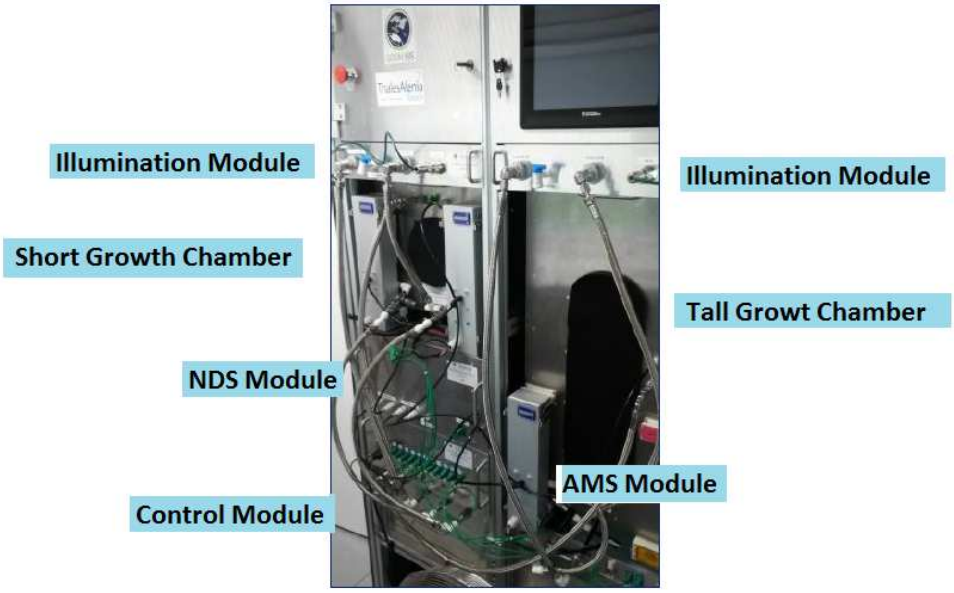


Figure 40: EDR Like P/L

ISPR RACK STRUCTURE

The main ISPR structure is composed from Bosch Rexroth aluminum profiles to favor implementation of multiple configurations in the rack development process, while limiting the unit mass. This flexibility has been required by the necessity of the system of being used as a research and development tool. Removable aluminum panels enclose the profiles frame in order to provide a barrier to the MTF environment while allowing easy accessibility for maintenance activities.

The structure is sized to be close to an ISS International Standard Payload Rack. The dimensions of the rack are:

- Width: 1060 mm (however clearance to the sides is required for operating the drawers)
- Depth: 800 mm (not including handles and drawer harness in the front; not including bracket in the back, currently not foreseen)
- Height: 1950 mm (not including elements for fixation to the ground; not including hangers for movement with crane)

The modular design allows for easy maintenance inspection. The inner part of the rack is accessible from the front side by removing the drawers (see Figure 41). Nevertheless, no lateral inspection is possible without dismounting the whole rack from its MTF location, and in any case no lateral ports have been foreseen.

Figure 41: Rack Maintenance

The drawers are completey removable. A clearance of 730 mm (not including clearance for the operator) in front of the rack is necessary. That feature is particularly important for the access to the Growth Chambers, since they are provided with later ports on the left side to allow inner operations (like those necessary for plant management). It is worth to say that in this case, it is not necessary to completely remove the drawer from the rack structure, but a partial extraction is sufficient for that.

ILLUMINATION SYSTEM

The illumination is provided by means of LED panels with the same performance and capabilities of the LED system implemented in the FEG:

- The LED panel is water cooled
- The LED Panel is powered at 230 VAC
- The LED are dimmable from 600 to 100 $\mu mol\ m^{-2}\ s^{-1}$ (with each wavelength independently controlled) via Ethernet SEA 9715 IF (into CompactDAQ module), including health status monitoring.

Figure 42: LED Panel and Camera

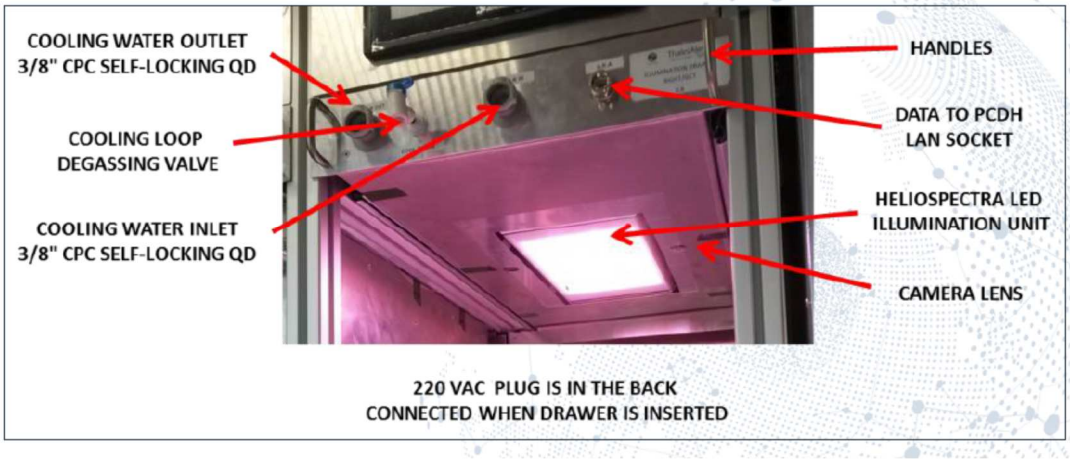


Figure 43: The illumination system

The LED Panel (Fig. 42) has been integrated in a drawer that provide not only the mechanical interface to the ISPR rack structure, but also the interfaces (on the front side) to the water cooling system and to the Control Unit. The system also includes a small camera (Fig. 42) for the plant health monitoring that is mounted close to the LED panel and is pointing down towards the growth area. Two drawers have been realized, one for the Tall Growth Chamber, the other one for the Short Growth Chamber.

Air Management System and Thermal System

Each growth volume has an independent air management system. The air management system includes:

- Temperature and humidity control system (THC)
- Major Constituents Control System (MCCS), managing the environmental pressure, as well as O_2 and CO_2 concentration
- Trace Contaminants and microbiological Control System (TCCS), removing organic gaseous contaminants (i.e. ethylene) as well as filtering out microbes and viruses.

Figure 44 reports a schematic of the technologies along the circulating air path as well as the preliminary distribution of the components within the growth chamber module volume.

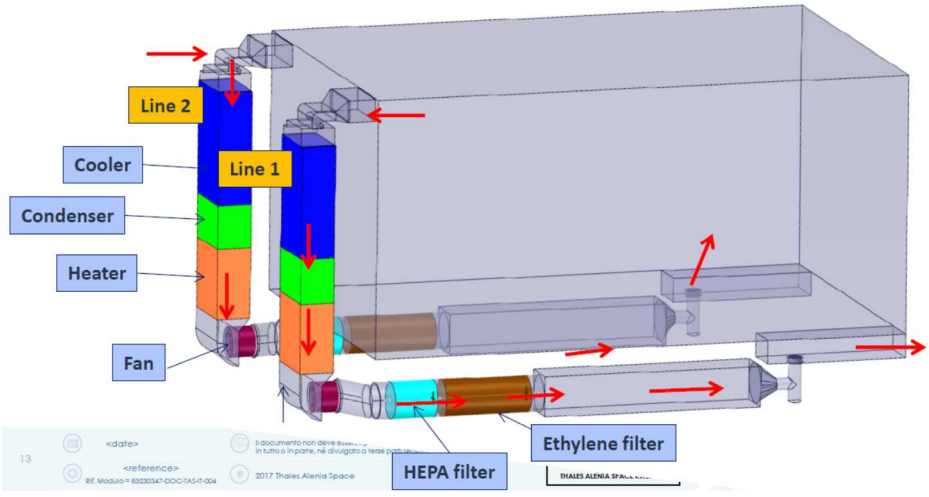


Figure 44: Air Management System

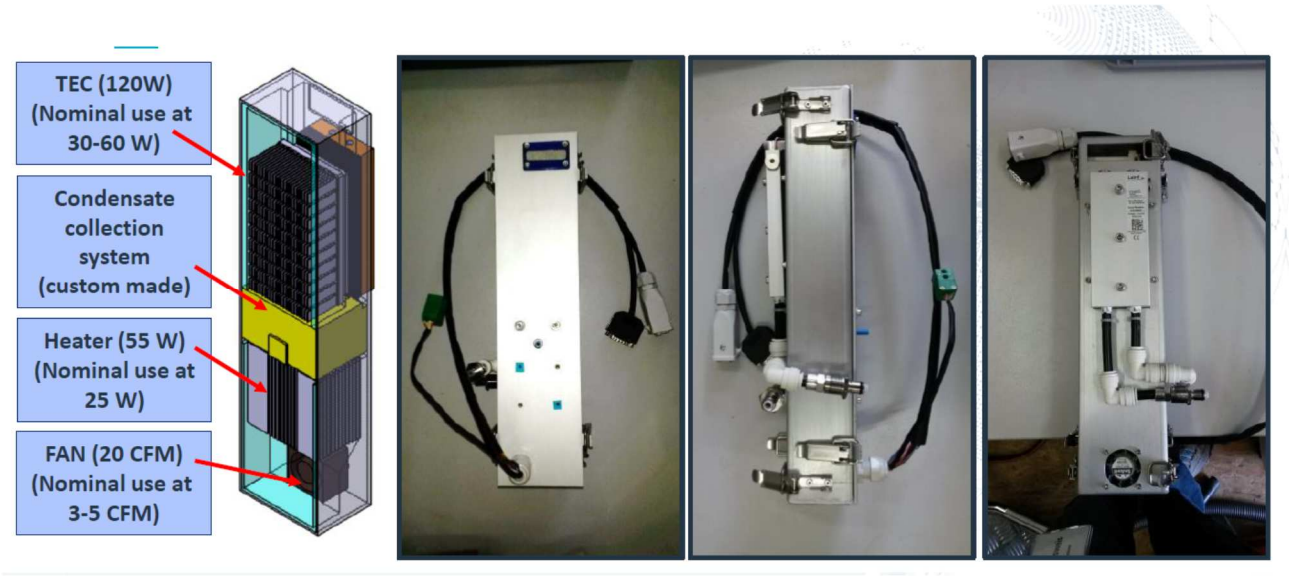


Figure 45: Temperature and Humidity Control Layer

Temperature and humidity control (Fig. 45)

The air extracted from the shoot-zone volume is cooled by a thermo-electric cooler (TEC, using Peltier effect) to remove sensible heat loads as well as latent heat loads through condensation of water vapor. The water vapor is then collected by gravity in a custom made recipient, and then pumped through a UV-LED based disinfection system to the DI water reservoir within the Nutrient Storage Module. The over-cooled air is then reheated with a PTC heater. Both the TEC and PTC heater are insulated (i.e. with 2 mm thick Armaflex) to guarantee efficiency. The TEC is assembled as an air to water heat exchanger, and the heat collected at the water side is removed by the cooling water provided by the MTF via the ISPR Rack Interface. Air temperature and humidity are monitored via a single multi-parametric sensor at the air extraction chapter, in order to provide feedback to the active control system.

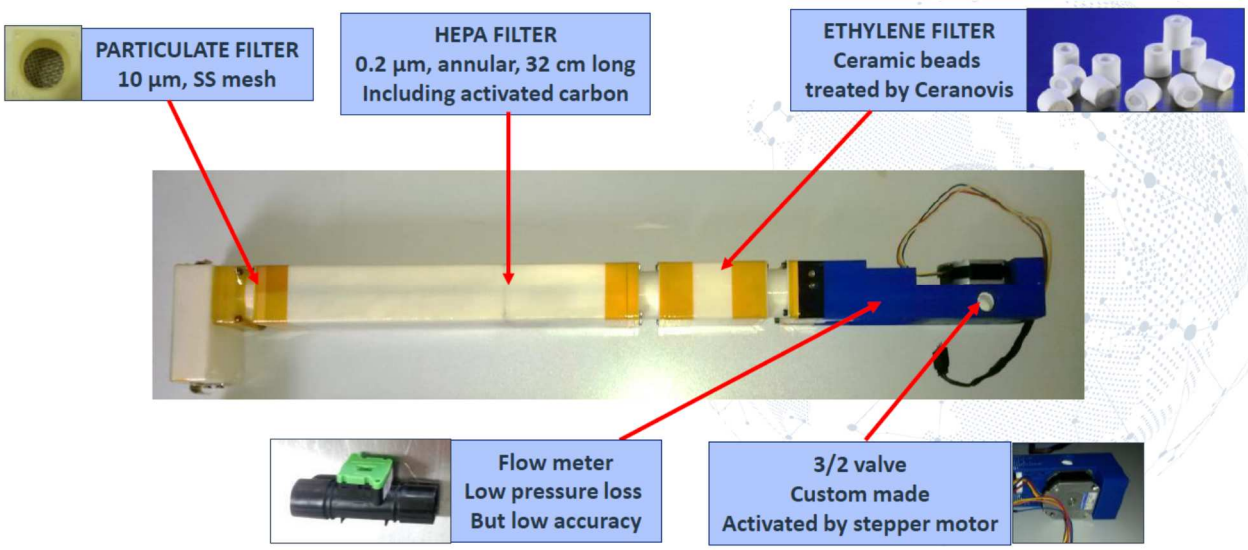


Figure 46: Trace Contaminants and microbiological control

Major Constituents Control

For oxygen and carbon dioxide concentration control, a semi-open loop strategy is implemented. In normal operations the shoot-zone air is circulated in a closed loop until the O_2 concentration rises to a certain threshold (i.e. not acceptable fire risk). Then air is exchanged with the (MTF by electro-valves) to equalize O_2 concentration and reach back normal levels. CO_2 is added as needed via a dedicated 500g CO_2 bottle. However, the same strategy adopted for O_2 concentration control could be also applied, depending on MTF nominal CO_2 concentration (when the CO_2 level is too low in the ISPR, air is exchanged).

In order to limit the phenomenon of rejection to the MTF of the air just injected from the MTF, injection is performed only from one of the redundant air management lines and rejection from the other one.

Trace Contaminants and microbiological Control (Fig. 46)

After passing through the THC elements, air passes through a 0.2 µm membrane for filtering of bacteria, viruses and particulate. An additional passive filter for organic contaminants removal is then placed downstream, prior to the reintroduction of the air within the growth chamber shoot-zone volume.

Given the periodic air exchanges between the MTF crewed environment and the shoot-zone volume (as per semi-open loop strategy described above), the following precautions for limiting cross contamination have been implemented:

Air collected from the MTF is introduced downstream the THC and upstream the TCCS (so no energy is wasted to cool/dehumidify air already at lower temperature and humidity)

Air rejected to the MTF is first processed through both TEC and TCCS (to reduce system water loss and avoid rejection of contaminants to the outer environment)

This precautions have constrained the possible position of the fans, which need to be necessarily placed downstream the THC and upstream the TCCS, with air injection from the MTF upstream the fan of line 1 and air rejection to the MTF downstream the TCCS of line 2.

<u>Nutrient Delivery Subsystem</u>

The Nutrient Delivery System (NDS) is divided among multiple modules (ISPR drawers):

- The nutrient storage and distribution module/drawer, containing the reservoirs (stock solutions, acid/base, DI water, nutrient solution), the delivery pumps and the UV-C condensate bactericidal system

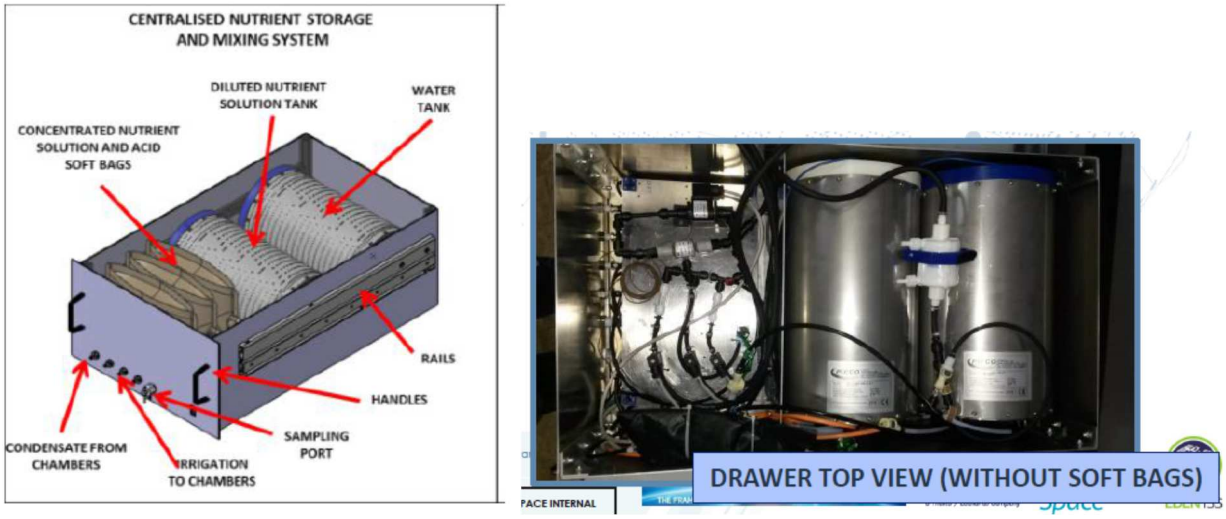


Figure 47: The Nutrient Storage and Distribution Drawer

- The root module within each growth chamber module/drawer, containing the growth substrate, its container and the sensors and actuators needed to guarantee appropriate distribution of water and nutrient solution within the different area of the substrate.

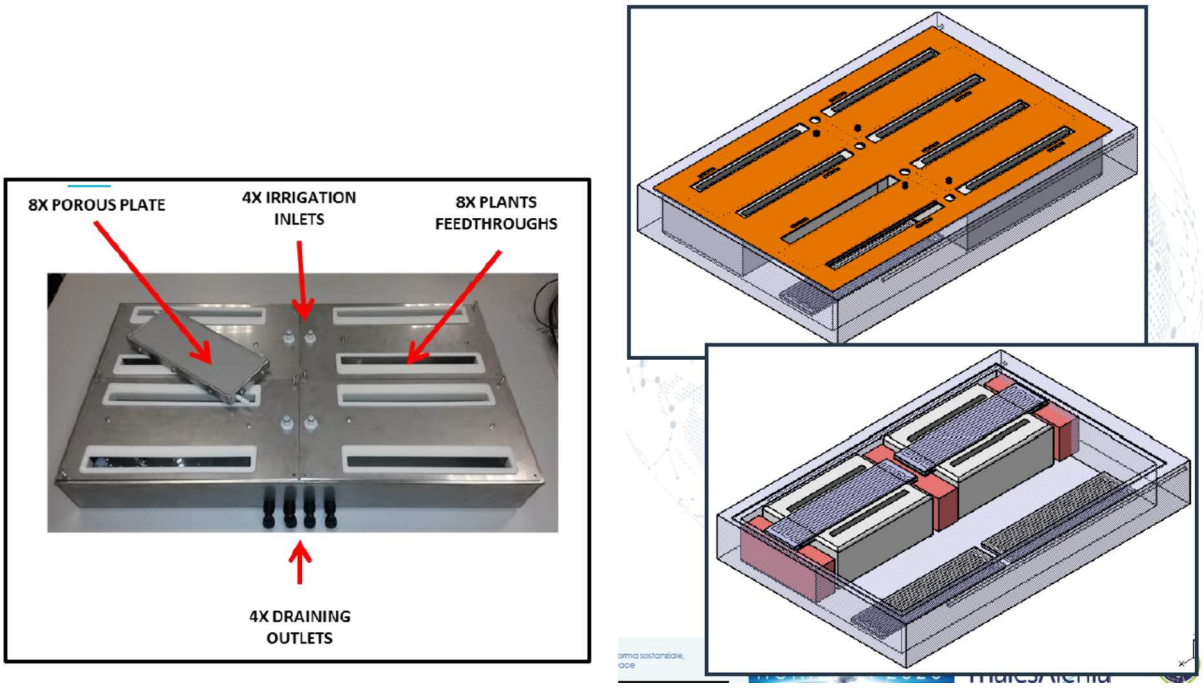


Figure 48: The Root Module

The NDS block diagram is reported in Figure 49. Either DI water or nutrient solution can be delivered to the root modules. The block diagram is explained as follows:

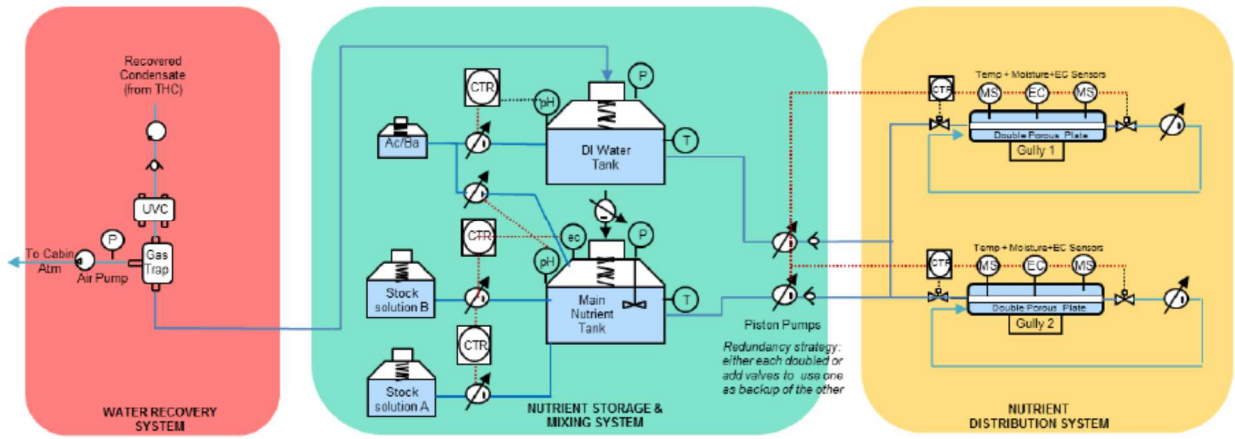


Figure 49: Nutrient Delivery System Schematics

Nutrient storage and distribution

DI water is used in case of salt accumulation within the root module (EC increment within the sub-strate or porous elements cleaning to prevent clogging). The DI water pH is monitored and controlled by acid/base injection. The nutrient solution EC and pH is monitored and controlled by water or stock solution (from ded-icated reservoirs) injection. Injection is allowed by LabVIEW® controlled piston pumps. An ultrasonic stirrer

allows homogeneous mixing of the nutrient solution within the reservoir. No temperature control is foreseen (only monitoring).
Concentrated solution tanks is flexible, replaceable (self-locking QD), stored dry and filled with water only before use. Water and nutrient reservoirs current baseline solution is a bellow tank, with Teflon bellow.

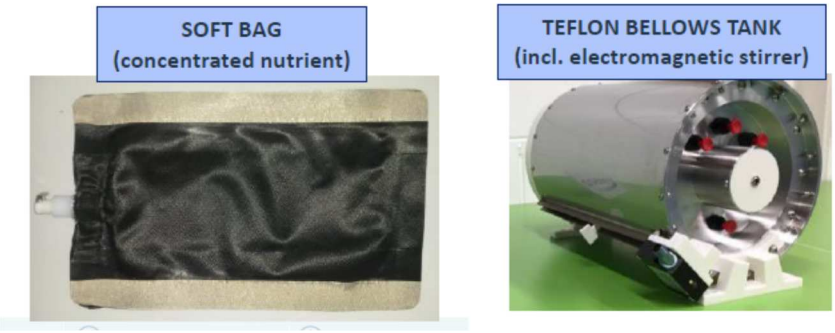


Figure 50: Nutrient Storage and Distribution Module Components

Water recovery
Condensate recovered from the THC will be disinfected with UVC-LEDs and then passed through a membrane contactor (gas trap) to separate the air from the water flow.

Root module
The baseline solution for the root module sees 4 (four) porous plates for nutrient solution distribution, placed parallel to the ground, on top of the substrate pillows. Additional 4 (four) porous plates are placed in the bottom of the root module and, by removing nutrient solution for direct recirculation via piston pumps, they simultaneously recall air from the shoot-zone volume allowing aeration of the substrate. Figure 51 reports the drawing of this solution.

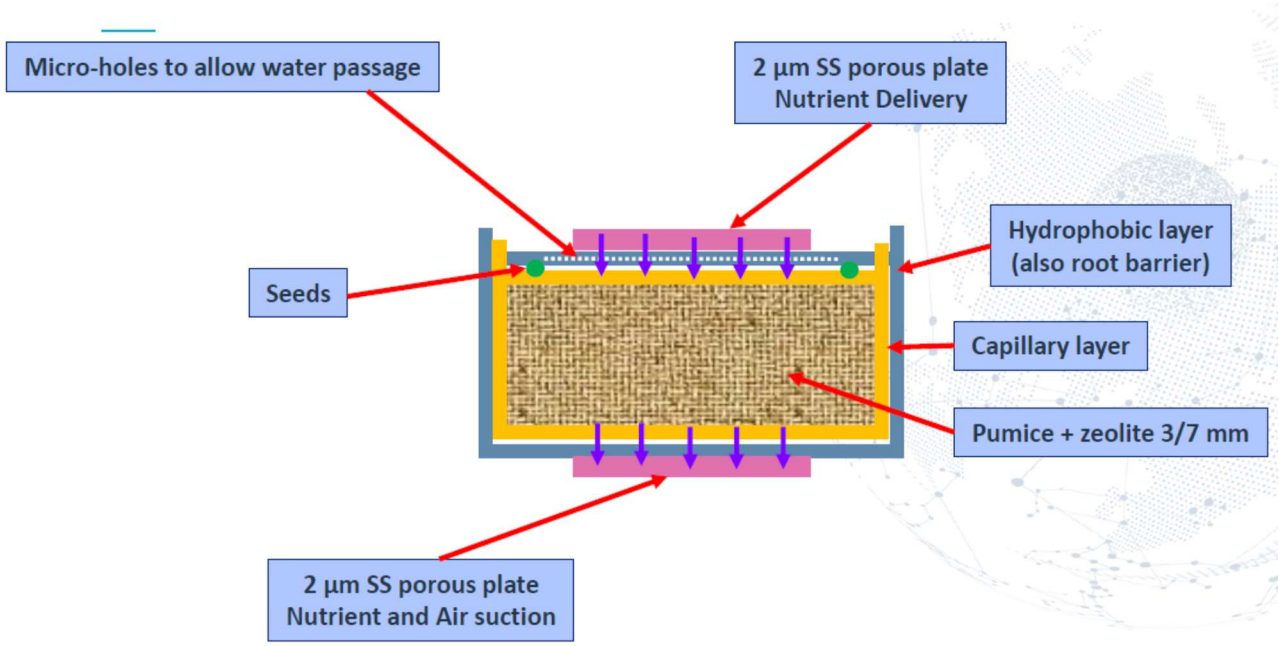


Figure 51: Root Module Concept

Figure 52: Substrate Pillow

The substrate is done of a combination of pumice and zeolite that ensures good performance in ionic exchange and in root zone aeration and seems to prevent molds proliferation. The substrate is contained in a pillow made of non-woven polyester that on one hand provide a full containment of the substrate, on the other hand allows for water/nutrient delivery towards micro-holes on its surface.

Substrate moisture, EC and temperature are monitored via sensors connected to a common data downlink port. Three moisture sensors per pillow will be used. EC will be monitored powering only one sensor each time, to prevent interference.

The connection of the Nutrient Storage and Distribution Module and the Root Module is done via a distribution system placed within the Growth Chamber that is composed of several actuators (electro-valves, pumps) and sensors and provides the interfaces to the 4 irrigations inlet and the four drainage outlets.

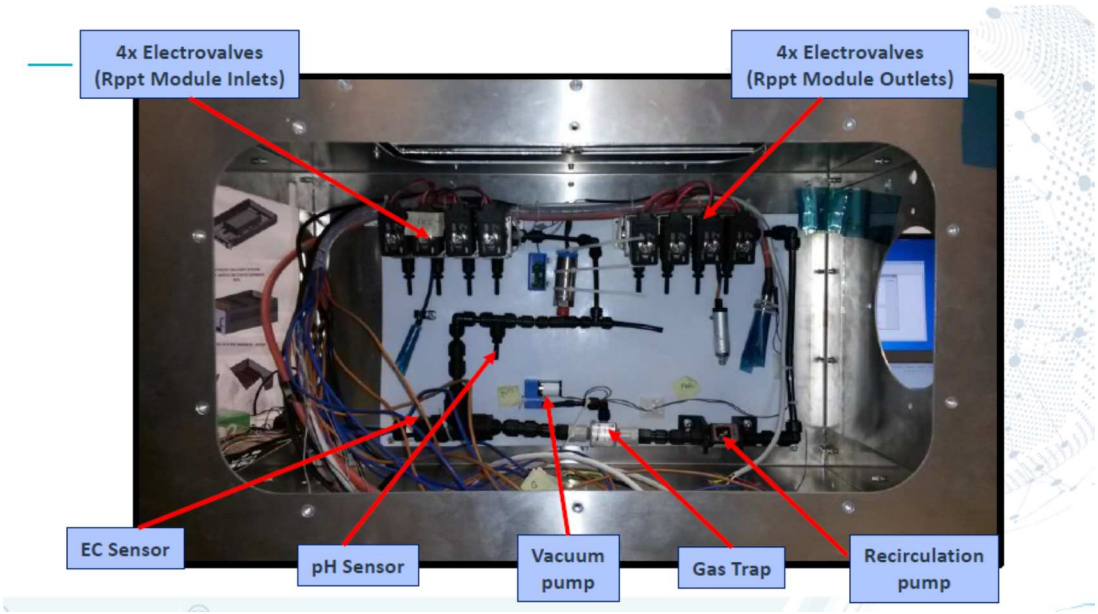


Figure 53: Nutrient Storage Module to Root Module interface

Command And Data Handling System

The Command and Data Handling (C&DH) System is housed in the Power, Command and Data Handling module/drawer (Fig. 54).

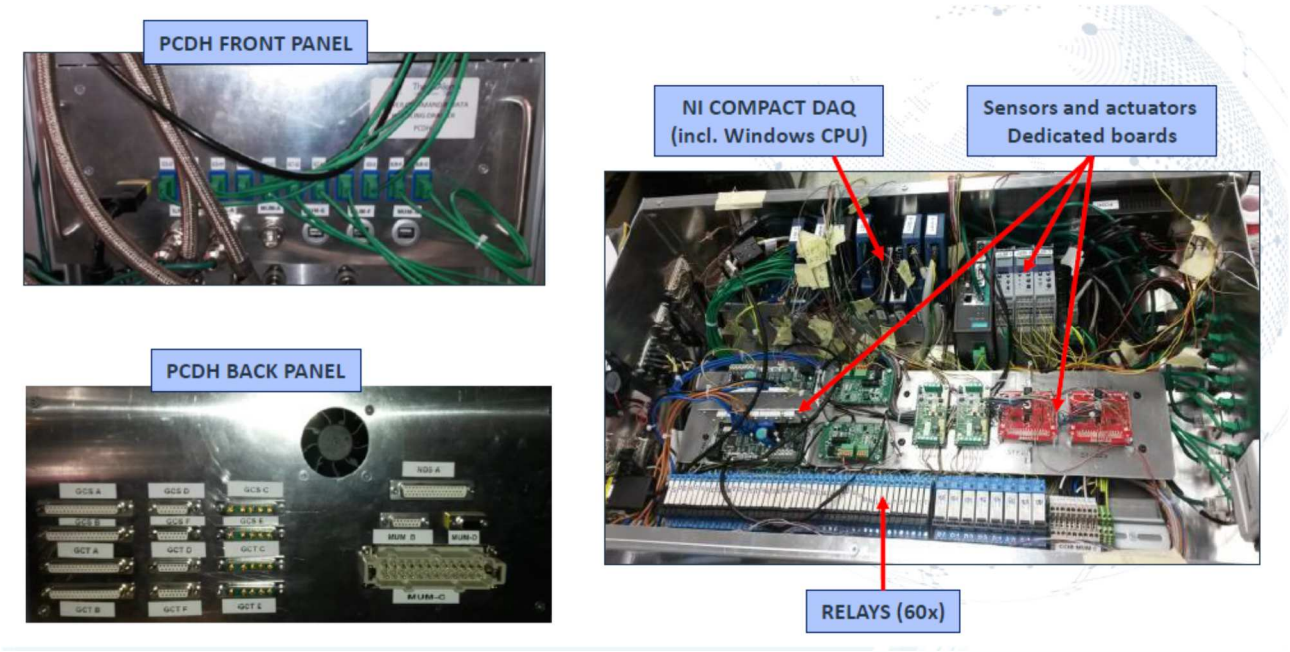


Figure 54: C&DH System

The general conceptual schematic of the C&DH system is given in Figure 54. Data are collected from the P/L drawer sensors into a NI Compact DAQ (cDAQ) board via dedicated I/O modules. Commands are generated by feedback control implemented within the cDAQ controller, and transferred to power relays via internal Digital Output (DO) modules. The different programs can be loaded onto the cDAQ board via rack-external signal, generated by a LabVIEW based computer and transmitted by LAN interface. The same interface is used for telemetry downlink.

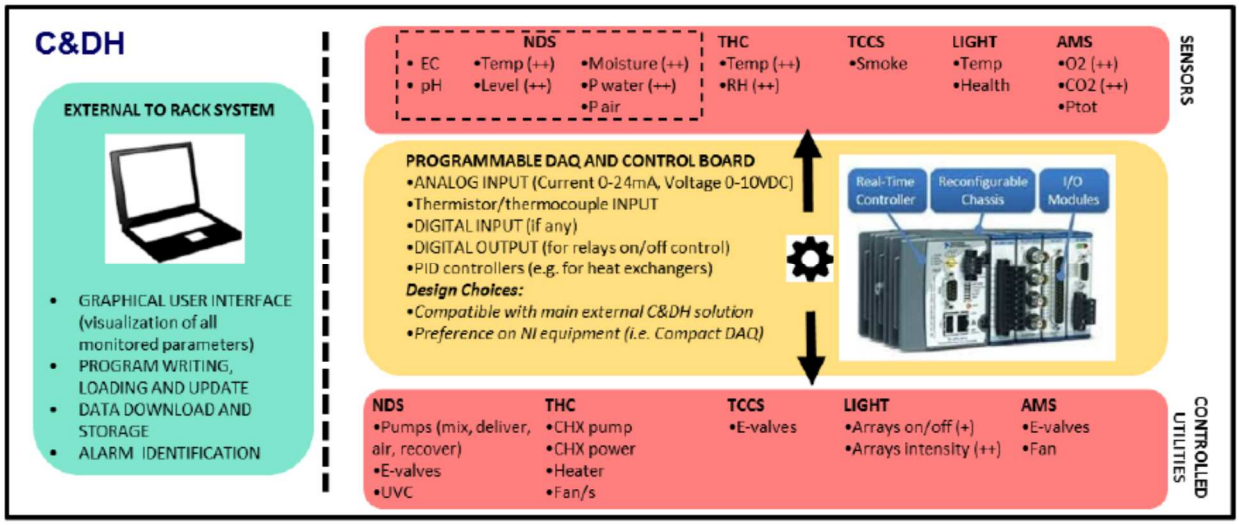


Figure 55: C&DH Conceptual Schematics

Power Distribution and Control Subsystem

Figure 56 reports the Power Distribution and Control System conceptual schematic. Power will be delivered from the MTF to the ISPR via 230 VAC, 10A electrical IF. 230 VAC to 24 VDC conversion will be provided within the ISPR volume, and is distributed to the different utilities via the commanded relays placed in the Command and Data Handling module/drawer.

Nevertheless, manual override of key utilities (i.e. illumination, irrigation) on/off conditions is possible, especially to allow maintenance.

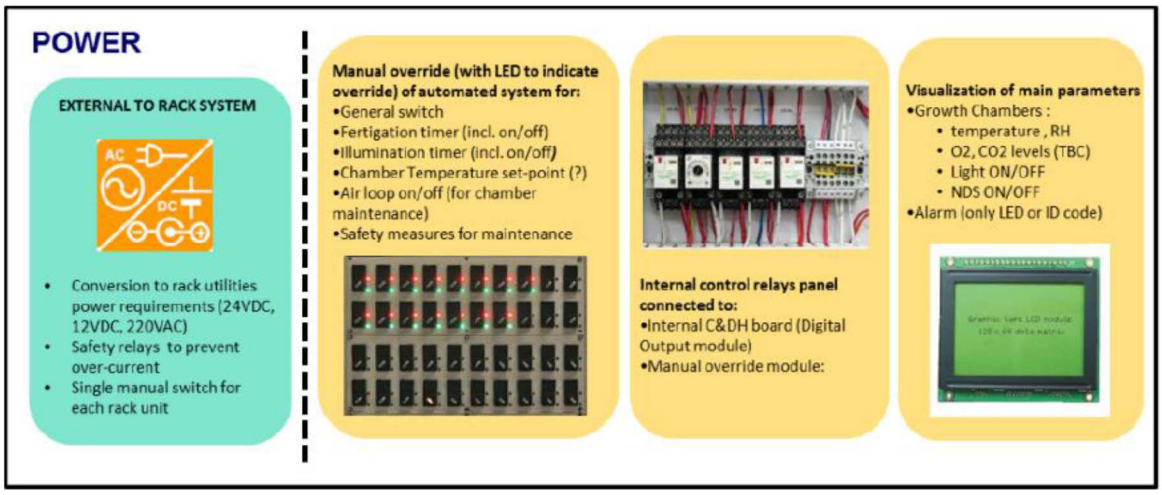


Figure 56: Power Distribution System Concept

Interfaces with the mobile test facility

Apart the mechanical interface, the ISPR rack interfaces the MTF via connectors placed on the lower part of the main structure (as per the Racks on board of the ISS), as shown in figure 57.

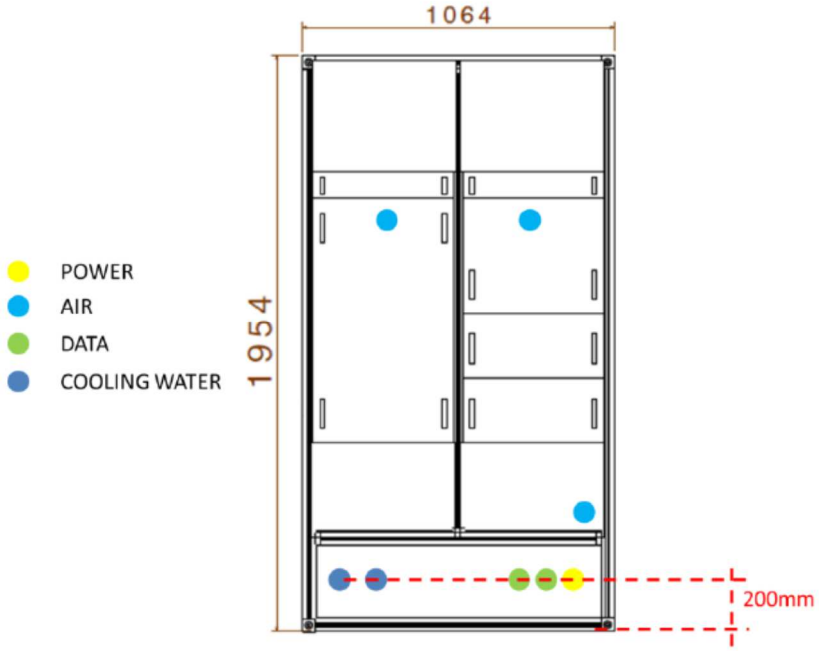


Figure 57: ISPR RAck to MTF Interfaces

Mechanical interfaces: the ISPR is installed in the MTF Service Module, on the right side just after the entrance door and before the AMS system. It is fixed to the main structure by means of 4x bracket with 6x M8 screws each in the bottom and one bracket on the top.

Electrical Interface

Type: 230 VAC, 10 A

- 230 VAC connector (plug) QUICKON system of Phoenix Contact

ISPR power budget:
• Peak mode: 1.5 kW peak
• Nominal mode: 0.65 kW

Cooling Interface

- Cooling water inlet: 190 kg/h flow and temperature of 16 – 20°C (pump not included in ISPR)
- Cooling water outlet: 25°C worst case (max water inlet temperature, peak power, no dissipa-tion to environment)

IF type: Self-locking ½" quick disconnect (QD) female

Data Interfaces

- LabVIEW system LAN socket – refer to NI cDAQ™-9137 datasheet
    - 63 sensors, 1 Hz, 16 bit estimation
    - 2 cameras, 2 MB/picture, 5 pictures/day

Smoke detector 9 pin D-sub connector – refer to Shako detection system Model RMS datasheet

8 EDEN ISS Operations

EDEN ISS is a very complex system that requires different skills and competencies to be correctly operated. In-fact besides the engineering activities (system configuration and control), the EDEN ISS operations requires agronomical skills for plant cultivation, and other skills to manage food safety and quality analysis and microbial control. Of course it is not possible to have all of them in one single crewmember, as matter of fact one single NMIII operator will be responsible for the EDEN ISS operations, for that reason a ground support network hosting all the necessary competencies has been deployed with the capability to remotely support the operations. Nevertheless the EDEN ISS operator, apart the management of complex cases, troubleshooting activities and/or particular plant medical treatments, is the prime in the management of almost all. He has to ensure the correct system setup and monitoring, the plant cultivation management, some critical Quality and Safety analysis, and the collection of sample for post mission analysis.

This chapter deals with the description of all the above-mentioned activities to be done in the Antarctica site. And even if it does not provides all the detailed instructions on how to handle the several activities (that instructions will be provided by means of dedicated procedures), it provides an important insight on what the EDEN ISS operator will be called to do during the EDEN ISS mission. Five area's have been identified:

1. **System operations**: the activities aimed at the configuration of the EDEN ISS S/S to define, maintain and monitor the environmental parameters (light intensity, temperature, relative humidity, etc), and to compose and provide the nutrients for the correct handling of the plant growth process
2. **Plant Cultivation:** the activities aimed at the management of the plants, from sowing to the harvesting
3. **Food Quality and Safety Analysis**: the activities aimed at the verification of the produced food quality (in terms of nutritional and organoleptic parameters) and safety (verification that the produced food is safe for human consumption)
4. **Microbial Analysis**: the activities aimed at the collection and storage of sample for post mission analysis, and the on-site analysis by means of the E-Nose equipment. The possible decontamination activity is also included in this area.
5. **ISPR Operations**: As for the system operations, they are the activities aimed at the configuration of the ISPR to define and control the growth cycle parameters.

8.1 EDEN ISS S/S Monitoring and Control

8.1.1 General

The EDEN ISS equipment's have been designed to permit plant growth in a controlled environment. Therefore the system provides the capability to control all the environment parameter that can affect the plant growth itself and to operate the greenhouse in an almost automatic way.

As described in section 7.3.7 all the control functions are explicated by the Argus system that is working autonomously once configured. The configuration is done in two different ways: manually and via SW.

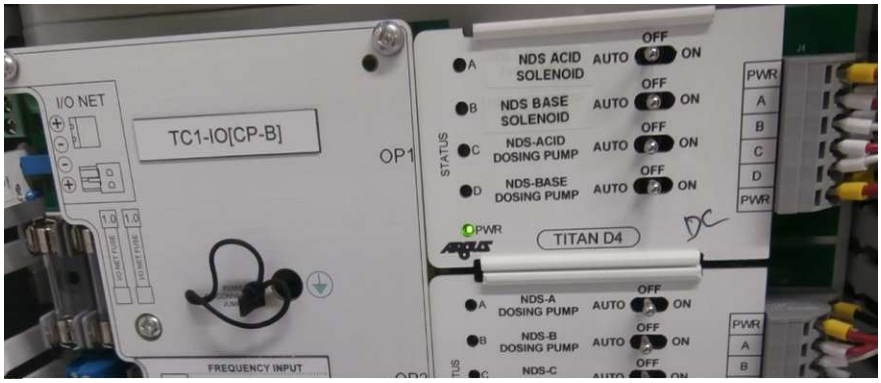


Fig. 58: Titan Board

The first level of configuration concerns the Titan digital relay boards (Fig. 58). In fact, by means of this board, it is possible to select the following element status:

- ON: in this status the element is always on and it is not possible to change the status via software
- OFF: in this status the element is always off and it Is not possible to change the status via SW
- Auto: in this status the element can be activated/deactivated via SW.

Therefore as part of the system initial configuration, the operator is requested to configure the switches in the desired position (for the EDEN ISS operations in "Auto" mode in order to allow for SW control).

The second level of configuration can be done using the Argus SW, running under the Microsoft Windows 10 operating system. This interface allows the operator to configure the Argus system itself, i.e. to define the control law, and to change the settings as desired. For the EDEN ISS operations there are ***five*** primary user screens allowing such operator interface.

1. **Home:** This is the main systems monitoring screen that displays important operational information and has links to screens for the various subsystems. Hitting the 'home' button at the top left on any Argus screen will bring you back to the home screen.
2. **Atmosphere Management System:** This screen shows sensor and management information for temperature, humidity, oxygen and carbon dioxide within the container. It is further subdivided into three additional control screens that include *overall sensor information*, *service section set-point control* and *FEG setpoint control*.
3. **Thermal control system:** The TCS screen shows temperature sensor data and valve activation settings for the external cooling system control.
4. **LED Lighting system:** The screen for the LED lighting system shows current wavelength settings and control activation for all 42 LED arrays in the illumination subsystem.
5. **Nutrient Delivery System:** This screen shows sensor readings and control settings for all the components of the nutrient delivery system.

The Argus Screens contain many different types of information and these are differentiated by foreground and background colors. Default colors are selected to maximize the visual difference between these different types of information.

- Green characters denote menu entries or "Shortcuts" to other screens. Left-mouse-clicking on one will take you to the screen or window that it represents.
- Blue characters denote settings that **can be changed** by the authorized user. Left-mouse-clicking on these entries will (with appropriate password access) allow you to make Settings changes.
- Red characters denote readings or values that are generated by the control system. You cannot change values that are displayed in red.
- Gray characters denote menu entries that are not currently available. You may need to log on with a different password to access these areas.
- **Black characters** are Factory-created labeling provided to help explain Factory Screens. You cannot copy or make Shortcuts to this labeling.

Settings such as temperature, RH, VPD, pH, EC, etc that can be changed by the user are indicated in blue text. Selecting these settings will engage the settings dialog (fig. 59) which displays the following information and options:

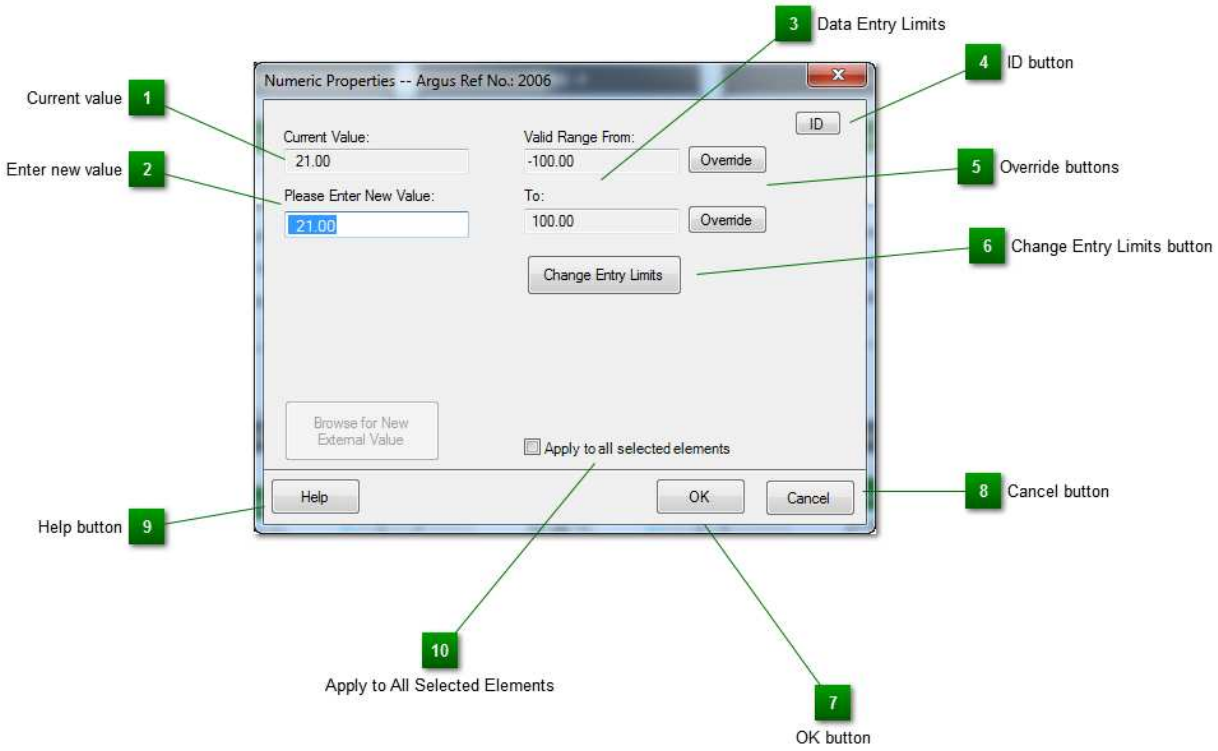


Figure 59: Argus Setting Dialogues Window

1. Current value: This is the current value stored in the controller for this item.
2. Enter new value: Enter a new value for this here.
3. Data Entry Limits: These readings display the current upper and lower data entry limits. You cannot enter a value outside if this range.
   There are three orders of Limits:
   - Firmware limits - imposed the data type (i.e. a 16 or 32-bit signed or unsigned number)
   - Application limits - imposed by the application logic (i.e. an entry limit between 0 °C to 35 °C designed to protect equipment and structures)
   - Management limits - imposed by management (i.e. an entry limit between 15 °C to 25 °C designed to protect a crop)
4. ID button: Select this to display more information about this item.

5. Override buttons: These buttons appear when either an Application or Management entry limit is in effect.
6. Change Entry Limits button: Select this to change or inspect Application or Management entry limits.
7. OK button: Select this to exit this dialog and save your changes.
8. Cancel button: Select this to exit this dialog without saving your changes.
9. Help button: Select this for help using this dialog.
10. Apply to All Selected Elements: Assigns the current settings to all other selected elements. To select multiple elements, press Ctrl and right-click for each element you want to select before opening the Properties. Then enter the values and click Ok. A tooltip is displayed if you move your cursor over this field explaining what it does.

The changes of settings have to be considered as system configuration, but they have no-effect without initiating them by means of a correct selection of the operational modes.

There are three basic methods of enabling or disabling (automatic vs. manual) control in Argus. Some systems are engaged through a simple enable/disable window which either allows the system to function (enable) or not function (disable), while others have manual on/manual off/automatic options that allows true software initiated user overrides of Argus hardware relays. For these to work, the hardware relay must be in the 'automatic' position. The third method of operational change is used for actuators that are proportionally controlled such as blowers or proportional valves. These have two options, 'Automatic' and 'User Override'. In the automatic position, the Argus control system will control the actuator according to the required programming and sensor feedback. In user override mode, the operator has the option to set for the position of the valve or actuator from 0% (closed) to 100% (fully open) or to any setting in between. The following fig. 60 shows the three ways to make operative the changes done.

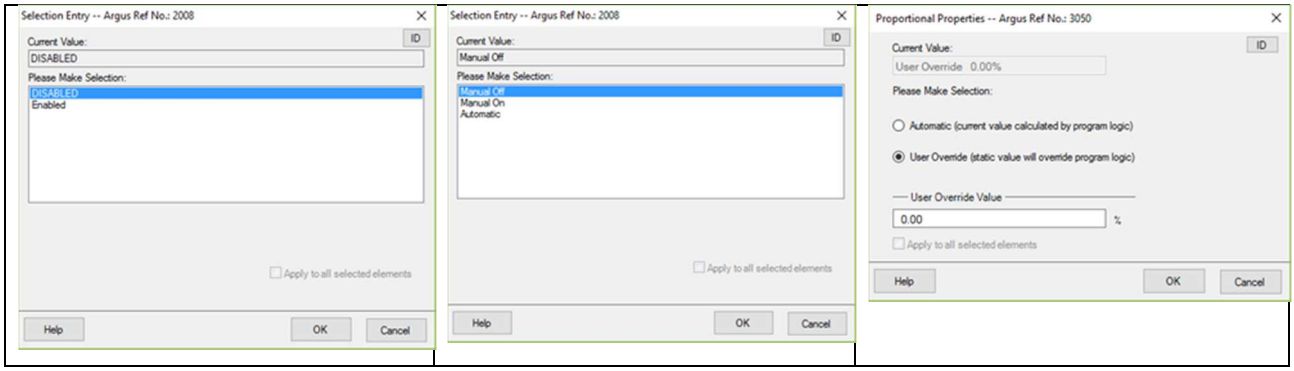


Figure 60: Operation change dialog boxes.

8.1.2 HOME screen

This is the main systems monitoring screen that displays important operational information and has links to screens for the various subsystems where changes can be made to operational set points. There are five main sections to note on this home screen (fig. 61):

Section 1: Systems monitoring

This area shows the main operational setpoints of user controlled hardware (e.g. lighting) as well as real-time system data.

Section 2: Power distribution system

This shows the current status of the power relays for the various subsystems. With control access, the settings can be changed between 'enabled' and 'disabled'

Section 3: System controls

This section displays current subsystem alarm status and links to the subsystem control screens. Selecting any of the green system names will take you to the screen for that subsystem.

Section 4: Graph reports

Selecting the Graph Reports heading will lead to a collection of saved graph reports. Commonly used reports are shown in the box.

Section 5: Time and date

Time and date as well as a link to the System Clock and Regional Settings screen are shown here.

Figure 61: EDEN ISS Main Screen

8.1.3 Power Control System Operations

The Power Control System manages the distribution of the electrical current to all the MTF subsystems. As far as the operations are concerned three main aspects have to be taken into account:

- The enabling of the power lines to all the MTF subsystems and components via the manual switches on the PCDS Main Power Box
- The configuration of the Titan Board switches
- the activation/deactivation of such subsystems done via Argus SW commands

As far as the first point is concerned, all the power switches have to be put on the ON position to enable the power lines to all the MTF components, including all the subsystems for the FEG operations. In principle, this should be a one shot activity, to be done at the beginning of the operations and right after the system mechanical setup, but that is not completely true. In fact, several maintenance activities requires the power lines disabled as per safety requirement and as a way to control the electrical shock hazard during the operations. For this reason in some cases, i.e. for some maintenance activities, and even if the system can be deactivated via SW commands, it is also necessary to directly operate on the Main Power Box, by switching off the affected system.

The second point is related at the configuration of the Titan relay board as described in the previous chapter. Also in this case, the configuration has to be done as part of the initial configuration of the MTF, and is aimed

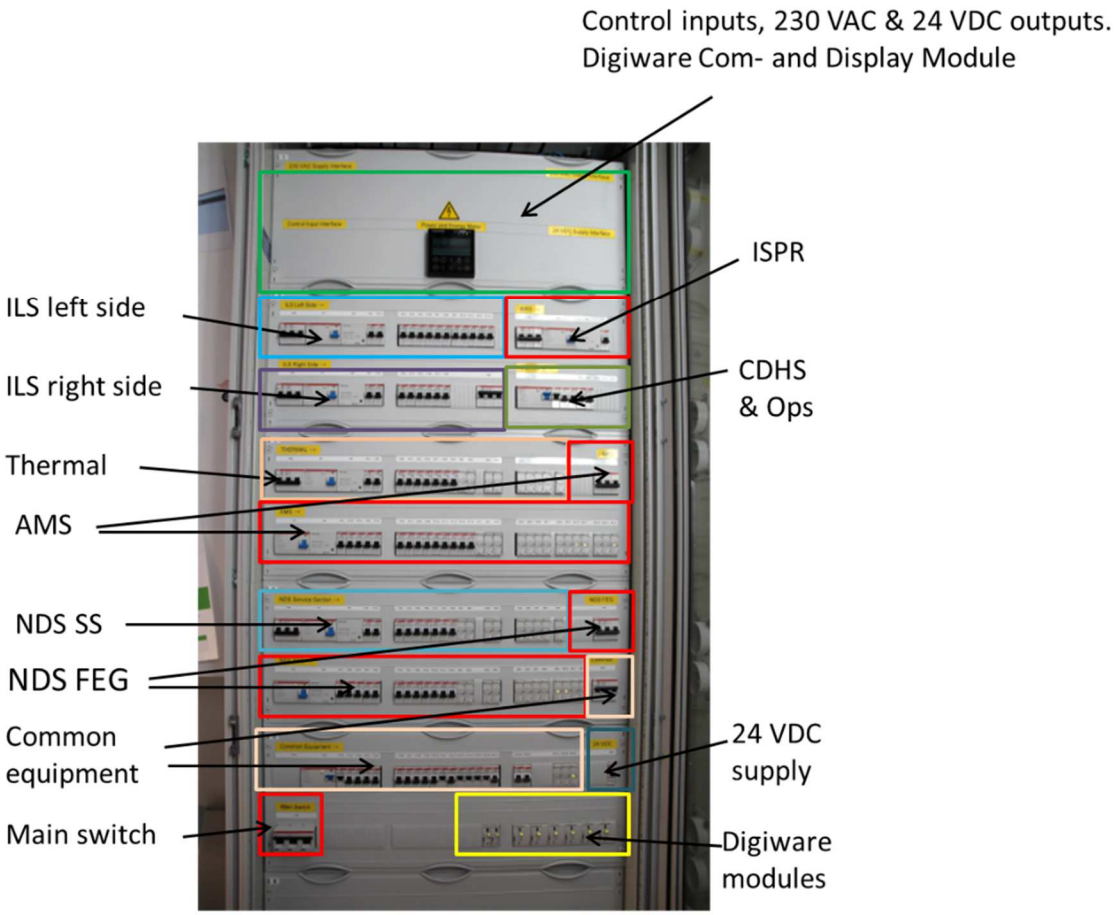


Figure 62: PCDH Main Power Box

Figure 63: Power Distribution System Argus Display

at putting the switch to “”ON” or “Auto” depending on the subsystem and on the requirement to command or not the element via the Argus SW.

The above-described points represent a prerequisite for the usage of the Argus Displays, and in particular, the one relayed to the Power Distribution System Display, that allows enabling the control for all the subsystem in terms of activation/deactivation, that in any case has to be done via the dedicated commands capabilities provided in the dedicated Subsystems displays. As for example, the SW activation of a pump of the NDS, is done via a command in the NDS dedicated display.

8.1.4 Atmosphere Management System Operation

Most part of the signals and the commands necessary to monitor and actuate the AMS systems are sent to and received from a remote control panel and managed by ARGUS. The functions that can be operated in local are related to the Air distribution, in detail constant flow valves louvers and tangential fans, and to the AMS unit, mainly control and substitution of filters.

In the AMS unit, the fans (2) are activated always, because it has to keep the air in movement continuously. These fans have an alarm relay to signal the failure on remote panel and a control input 0-10 VDC/PWM. Acting on that is possible to change the speed of fan and of consequence the performances and the power consumption. The control of the fans is made also by two flow meters, one installed after the fan on the top and the second after the filters: those flow meters has an output signals 4-20 mA suitable for alarms (i.e. the fan is shut off) and for a limitation of the fan speed.

In the dehumidification function the temperature of the heat exchanger is kept constant (by the Thermal Control), the air temperature is checked by two temperature transmitters, one (redundant) at the outlet of the FEG and one (still redundant) at the inlet: those sensors activate the heater (from 0 to 3 kW) to obtain the set value. The function water condensed recovery is automatic: a level sensor in the water condensed tank activates the suction pump, with an on-off logic type.

The function done by the O_2 sensor, one, installed at the outlet of the FEG, is to send a measure of the O_2 level to the control panel, just to record the O_2 production.

About the CO_2 system, two CO_2 sensors are installed in the air ducting of the AMS unit, one at the outlet of the FEG and one at the inlet, after a CO_2 injection point. In this case, those sensors will send a signal of the CO_2 level to remote panel (Argus). From this panel will start a command, in case of level lower than the set value, to open the solenoid valve which intercepts the gas line before the injection point. The CO_2 quantity injected will be regulated on the base of number of openings of the solenoid valve, keeping a constant opening time.

The air distribution system within the FEG has some manually operations to change the default setting. First of all, the louvers installed on the horizontal ducts are closable, partially or totally, in order to change the air quantity for a different zones of the shelves. Another manually operation will be the control of the speed of the tangential fans (8) installed on the top of FEG to improve the air circulation : for each fan is available near the fan, in local, a speed controller manually operated, in order to fine adjust, if necessary, the air circulation.

The relative humidity is checked by two sensors, integrated in the temperature transmitters. Those sensors check the RH of the air flow at the outlet of the FEG and again, after dehumification, heating and filtration, at the inlet of the FEG: the measures are sent to the remote panel. From the remote panel, when the value is lower of the required set point, a command will be sent to the humidifier(s) which automatically start. Also in this case the control will be done with an on-off logic, with a number of actuations of humidifier, keeping a constant time for each actuation.

As described before, most part of the operations are automatic and managed by Argus. Nevertheless some operator checks could be planned in order to monitor the status of the AMS system:

- the verification that all the sensors readings are in the required range
- a control of the water level in the condensed water tank (an obstruction can be cause flooding)
- a control of the filters status (pressure differential – media colour)
- a control of humidifier connections with the internal water piping (flood risk)
- a control of the CO_2level in the storage cylinders
- check of the measures detected by the sensors with an independent one

To state a corrective maintenance it has to define before a troubleshooting, comparing all the information with the function logic of Argus and the alarms on the control panel.

The main landing screen of the AMS shows basic current sensor information for the cold porch, FEG and service sections (fig. 65). Also shown are links to Alarm and I/O screens, however these are not required for day to day operation and should only be accessed by trained users. This main landing screen also shows two TABS that lead to the specific operational screens for the service section and the FEG

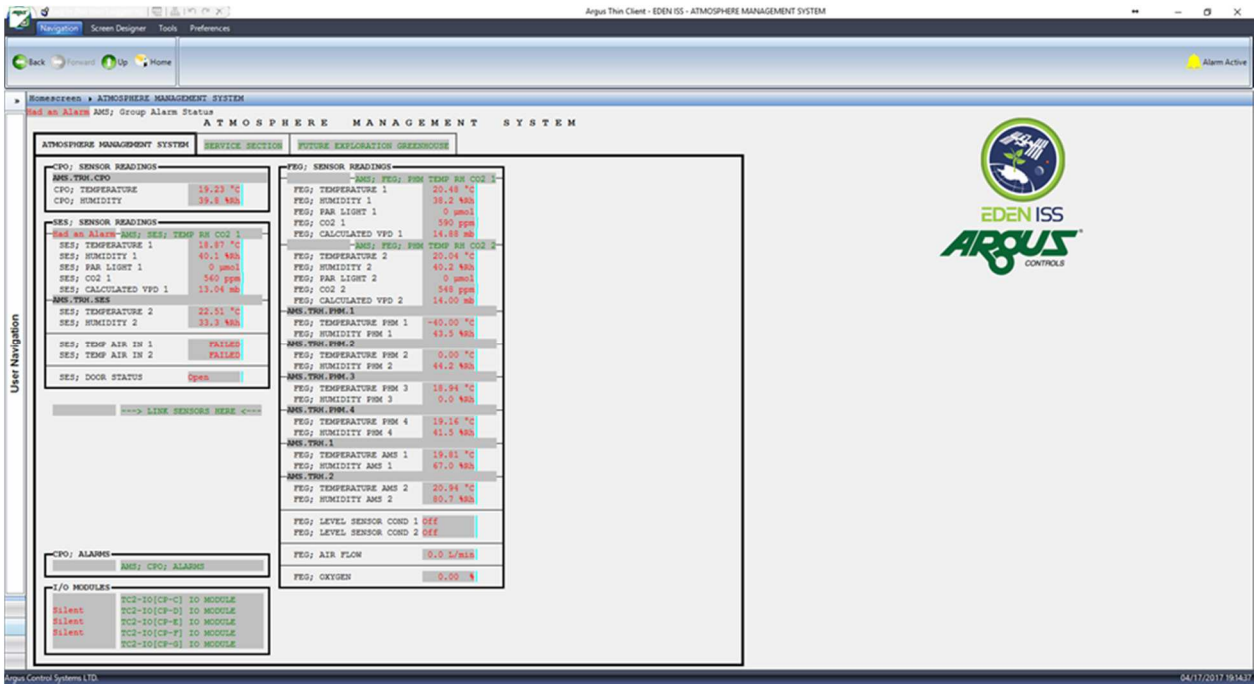


Figure 65: AMS Screen

By selecting the Service Section Tab (Single click on it), the Service Section Display opens providing not only the same monitoring capability of the Higher level AMS display (as matter of fact there is a duplication of the acquired sensors values), but also the possibility of operational changes of the Service Section environment conditions.

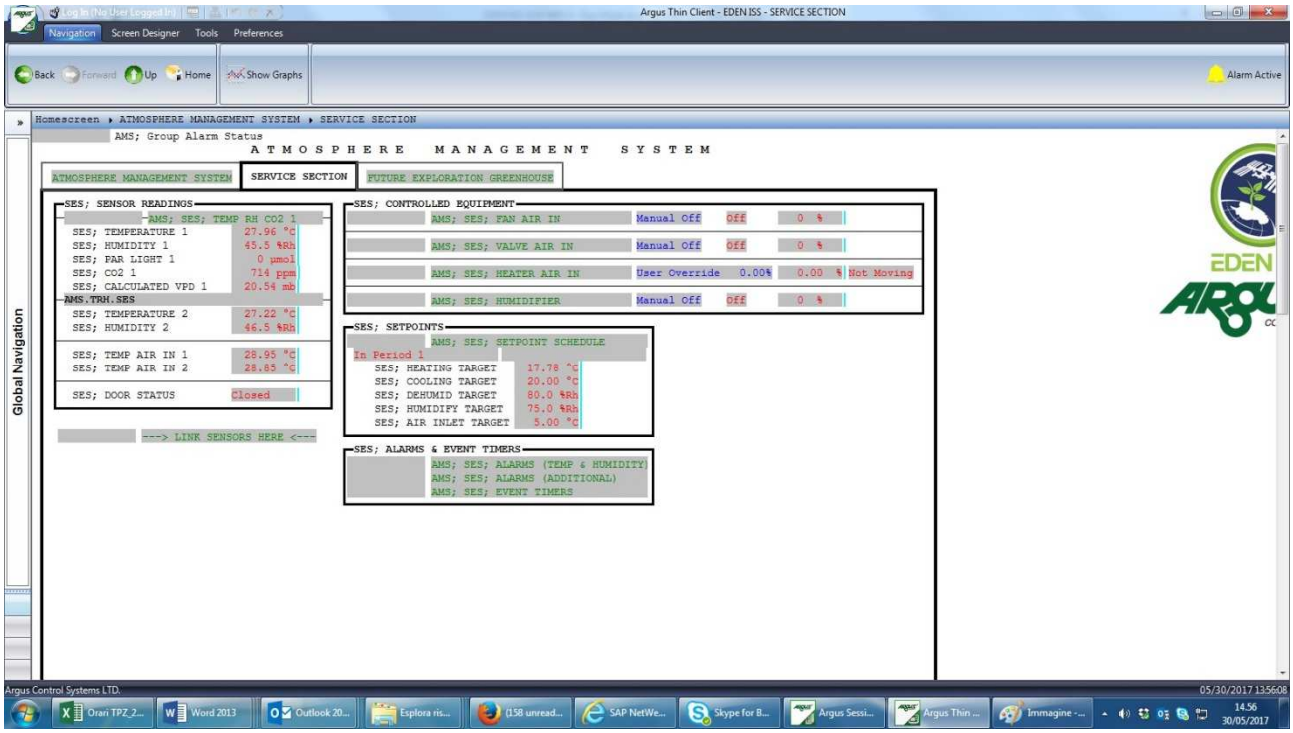


Figure 66: AMS – SS Display

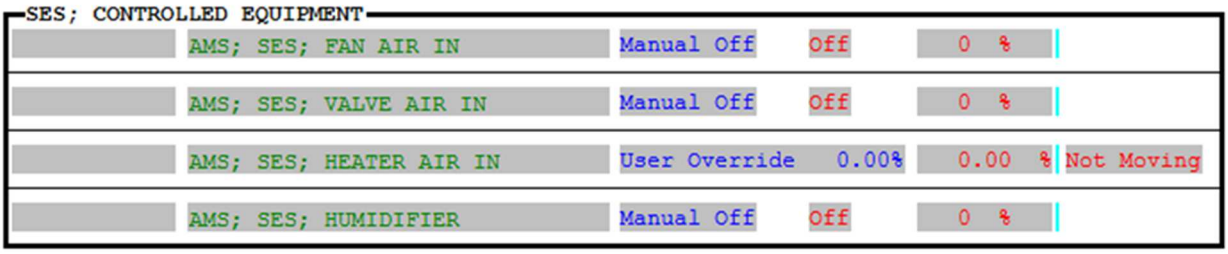


Figure 67: Operation control for the service section AMS actuators

In particular the CONTROLLED EQUIPMENT box provides the capability for enabling and disabling control of system valves, the heater and humidifier. The fig. 67 shows that the fan, the valve and the humidifier can work in autonomy or alternatively the operator can activate/deactivate them. The heater can also work in autonomy, but the operator has not only the possibility to activate/deactivate it, but also the possibility to define any settings between this two limits.

By means of this panel it is also possible to define a scheduling of the activities, i.e. to differentiate the control for different periods of the 24 hours. The tool provides the possibility to define up to 8 period, nevertheless for the for the EDEN ISS it is envisaged to differentiate the control between the day and the night. The figure 68 shows how the control can be defined and what are the parameters that can be set. As expected the only period 1 (Day) and period 2 (Night) are enabled, all the others are disabled.

For each period there is a COOLING TARGET and a HEATING TARGET. The minimum separation between the two values should be no less than 1.0 C. If control is set too tight, heating and cooling control will oscillate. For example, if a day time temperature of 22.0 C is desired, the HEATING TARGET should be set to 21.5 C and the COOLING TARGET set to 22.5 C.

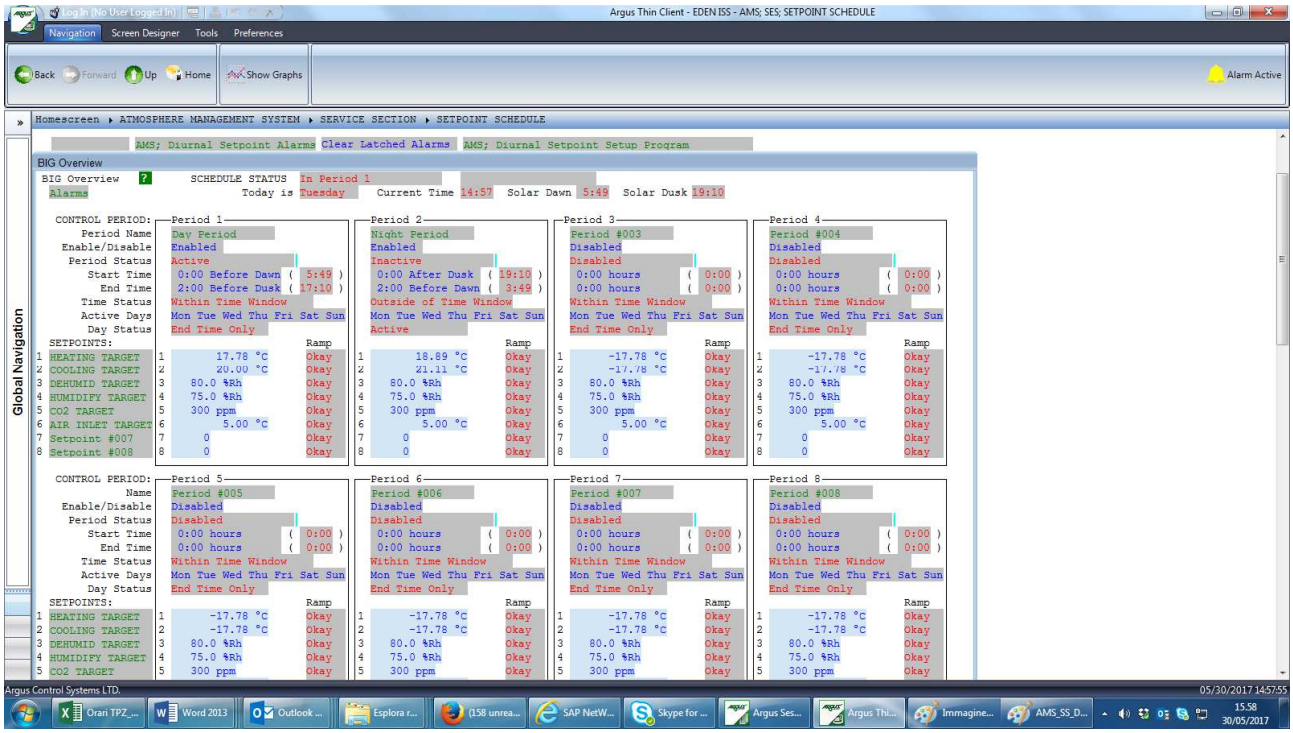


Figure 68: Argus Activities Day/Night period activities scheduling

As far as the Humidity Control is concerned, for each period there is a DEHUMID TARGET and a HUMIDIFY TARGET. The minimum separation between the two values should be no less than 5%. For example, if a day time humidity of 65% is desired, the DEHUMID TARGET should be set to 67.5% and the HUMIDIFY TARGET set to 62.5%.

The FEG Screen provides similar possibility, with in addition the possibility to control the CO2 level.

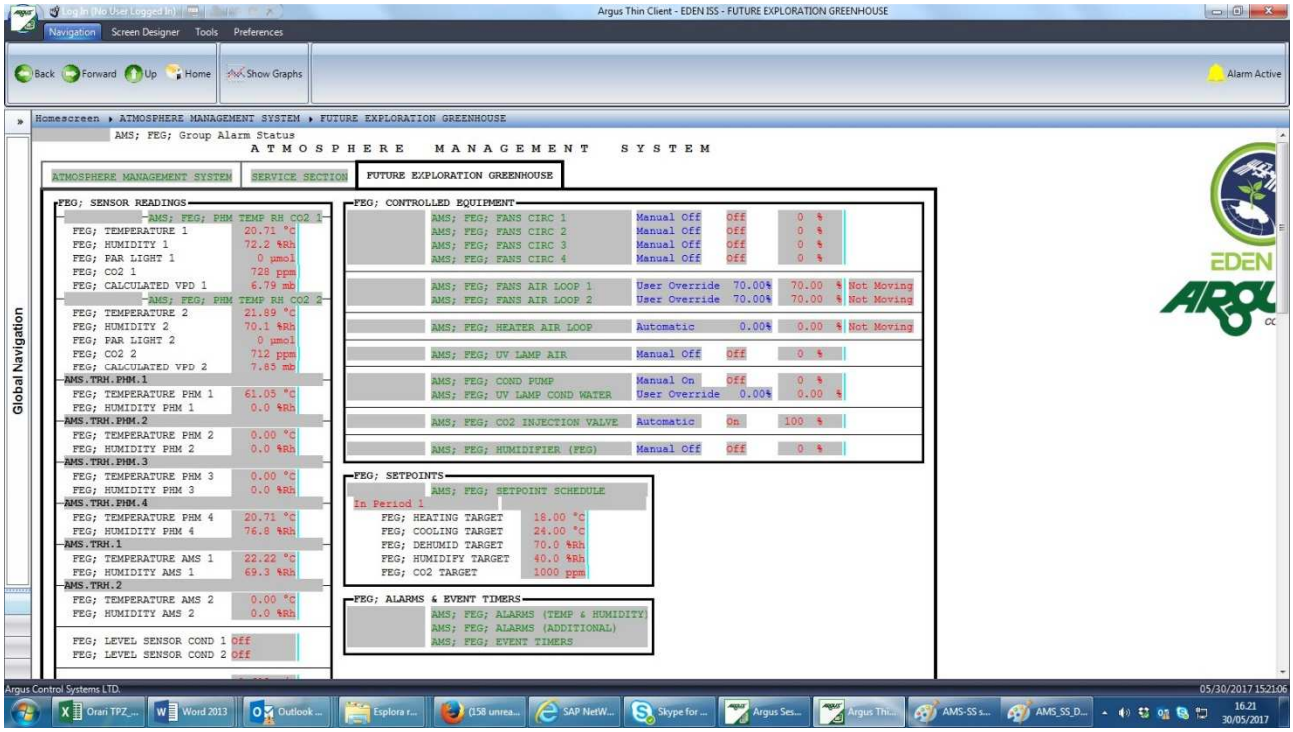


Figure 69: AMS - FEG Display

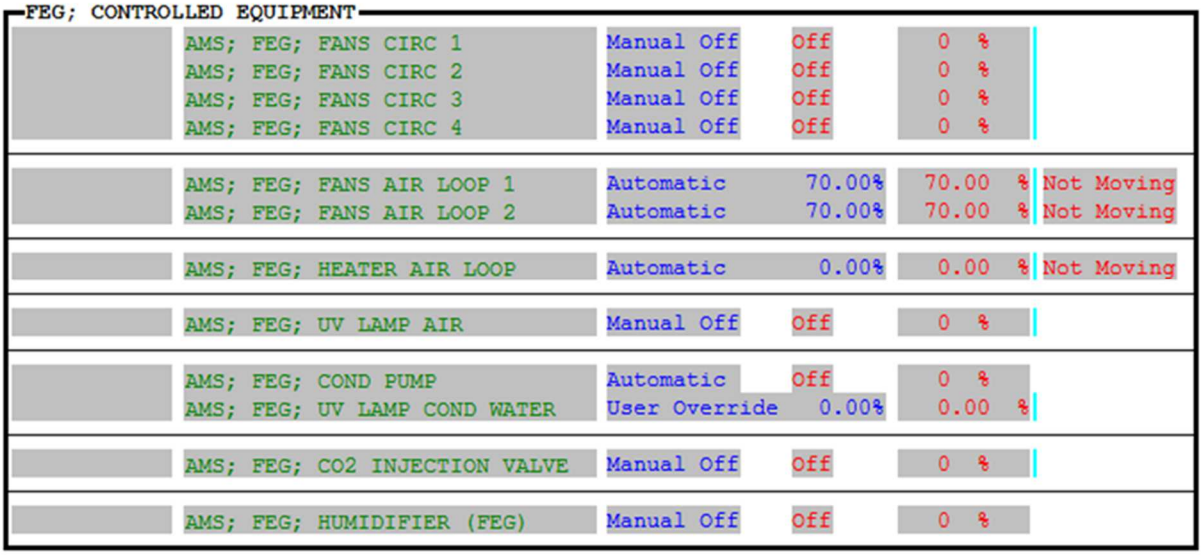


Figure 70: FEG Controlled Equipment

Chamber gas composition is controlled by CO_2 analyzer feedback to the Argus control system that operates a solenoid injector for carbon dioxide enrichment. Pure gas is supplied by a pressurized gas cylinder located outside the container. There is no method employed for CO_2 removal other than photosynthetic uptake or container venting. To enable CO_2 control, go to the AMS landing page and change the AMS; FEG; CO2 INJECTION VALVE parameter from Manual Off to Automatic. Disabling, which should be done prior to any system maintenance or when the system has no plant material, is done by switching to Manual Off. To change the CO_2 concentration setpoint, select the AMS; FEG; SETPOINTS SCHEDULE to show the schedule screen and change the **CO2 TARGET** value to the desired value. Valid parameters are from 0 to 2000 ppm.

8.1.5 Thermal Control System Operations

The thermal control system is responsible for providing chilled water to the AMS, the lighting systems and the ISPR Rack. As the other subsystems it is controlled by the ARGUS system.

The TCS landing screen displays sensor feedback and provides access to actuators operational settings. Actuator settings for the TCS valves and the free cooler are found within the **CONTROLLED EQUIPMENT** box.

Three-way valves in the thermal system piping are controlled to adjust the amount of heat which is removed from the sources and rejected to the outside. The ARGUS system automatically adjusts the settings of these valves to maintain coolant temperatures within specified ranges. Nevertheless the operator, changing the status from Automatic to User Override, can define the valves opening to increase or decrease the heat rejected as necessary.

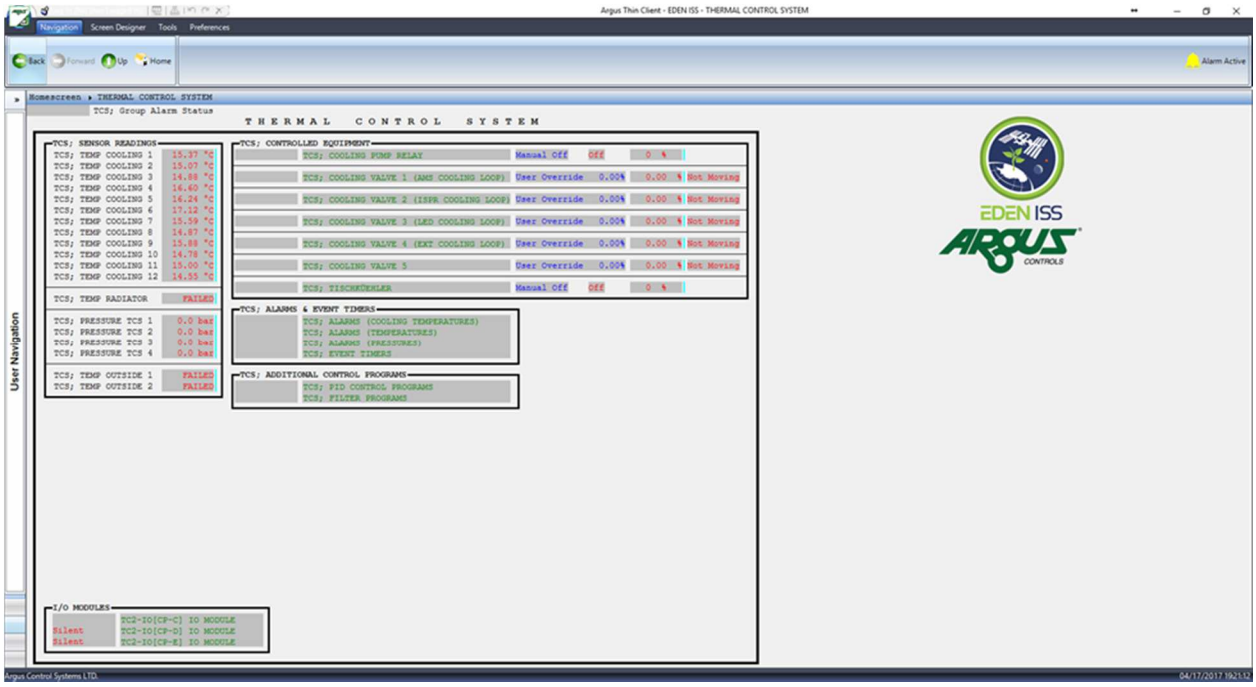


Figure 71: Thermal Control System Main Screen

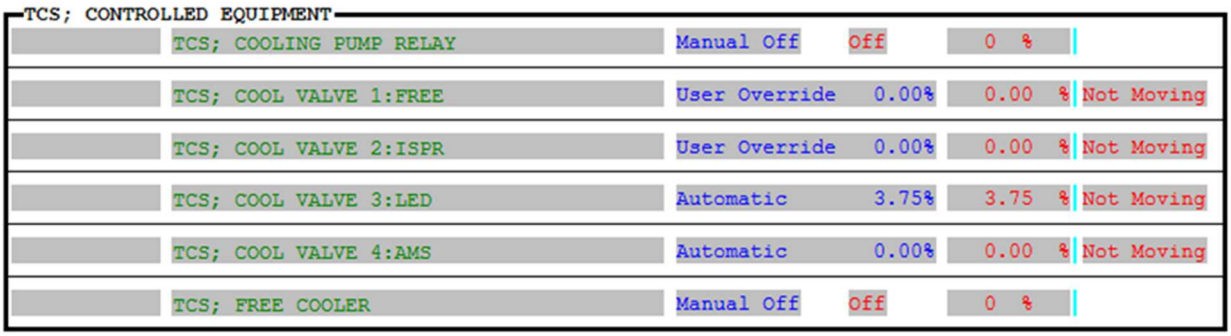


Figure 72: TCS; Controlled Equipments

Apart a daily check of thermal system parameters (e.g. pump flow rates) in the TCS display screens the operator is also requested to

- Weekly check of pressure gauges and thermometers
- Periodic (e.g. monthly) visual check of the free cooler to identify potential icing problems

Argus can also take some automatic action in case of problems:

- Display of warnings if pressure measurements fall outside of acceptable range (0.5 – 1.5 bar)
- Display of warnings if coolant temperatures fall outside of set point range
- Display of warnings if pumps produce an error message

Following the warning messages, the operator, depending on the issue can react as below:

- Check for leaks, repair leaks, and refill the system if the pressure drops below 0.5 bar
- Check pumps and valves if pressure exceeds 1.5 bar
- Check pumps, valves and free cooler if coolant temperatures fall outside of set point range
- Check pumps if the pumps produce an error message

If pump is damaged, he can replace the pump (a spare is available) and determine if damaged pump can be repaired. If valve or valve actuator is damaged, he can replace the damaged part (spares are available).

8.1.6 LED Lighting System Operations

The Heliospectra LED lighting is operated by Argus through Ethernet cables connected to each of the 42 lights. Each lamp has separate control for timing and spectrum. To enable any of the lamps, change the operational status from Manual Off to Automatic on the LED lighting system main screen. This screen displays current operational settings and provides the only control for lighting state (Automatic, Manual Off, Manual On). The configuration of each panel can be done going to the dedicated displays that allows the setting of the photo-period (for example a day/night cycle), the desired wavelength composition (blue, red, white, far red) and intensity. The configuration is done as per plant growth requirements and will be decided case by case with the support of the experts.

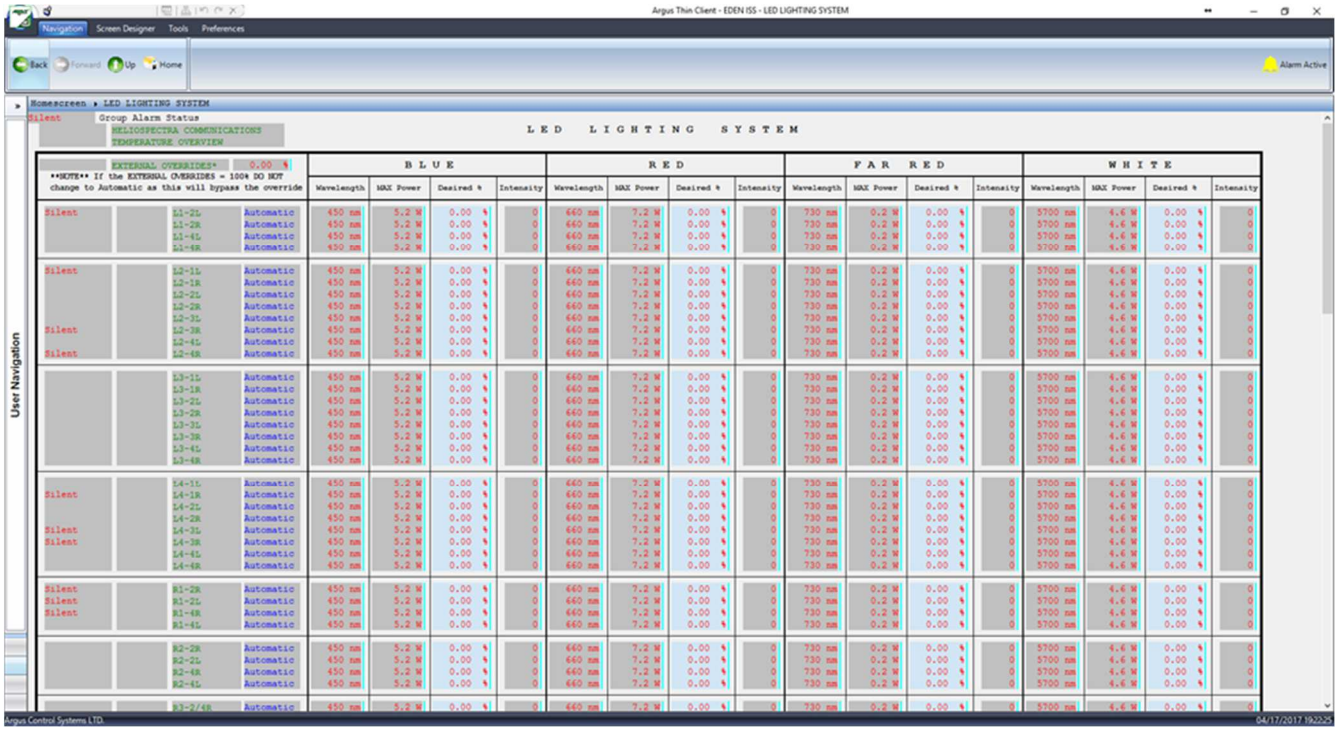


Figure 73: LED Configuration

Figure 74: Illumination Scheduling

8.1.7 Nutrient Delivery System Operations

The NDS subsystem operation will follow standard hydroponics plant production control algorithms and procedures. There are two main NDS bulk nutrient tanks, each can have a different nutrient recipe. Solution composition is dependent on feedback control from EC and pH sensors and user supplied set-points. Set-point level targets are maintained by the Argus Control System according to the following control algorithms.

Table 5: Argus Control Algorithms

Control	Argus response
If pH > set-point	Activate acid dosing pump for x[1] seconds and wait 30 minutes
If pH < set-point	Activate base dosing pump for x[1] seconds and wait 30 minutes
If EC > set-point	If tank is full, do nothing If tank is below full level, activate fresh water solenoid for x[1] seconds and wait 30 minutes
If EC< set-point	Activate A and B dosing pumps simultaneously for x[1] seconds and wait 30 minutes
If watering required (timer)	If sump tank level sensor detects over fill, do nothing If sump tank level sensor is normal, activate pump relay for x[1] seconds
If sump tank level sensor detects over fill	Turn off lighting and pump activation in the FEG and set sump tank full alarm
If fresh water tank low level sensor is activated	Set low water level alarm
If waste water tank high level sensor is activated	Set waste tank full alarm
If high pressure pump pressure sensor reads zero while pump is active	Set water pressure failure alarm
If water flow meter reads zero or below a user set threshold	Set water flow failure alarm Turn off lights to FEG
[1] These values will be determined an optimized during system testing and deployment.	

The nutrient delivery system screen (Fig. 75) shows sensor information and control operation for all parameters related to the movement of nutrient solution from storage tanks in the service section to plant grow boxes in the FEG This screen has two main sections along with ancillary control information. The systems are separated into the NDS Rack Operation (the system that manage the nutrient composition and control) and Irrigation Control and Scheduling (The system that manages the provision of the nutrient solution to the racks).

In general the operation of the NDS requires to:

- enable pH control for either or both NDS nutrient tanks
- enable EC control for either or both NDS nutrient tanks
- ensure adequate mixing of the nutrient solution
- maintain an adequate level of the nutrient solution within the tanks

pH control (Fig. 76)

Nutrient delivery system pH control setpoints are located on the NDS landing page. To change the pH setpoint value, select the **pH Setpoint** for either tank 1 or tank 2 and enter a new value when prompted by the Argus control system). In general, values should not be set below pH 5.2 or above pH 6.5.

To enable pH control for either or both NDS nutrient tanks, the four acid and base actuators must be set to Automatic operation on the NDS landing page

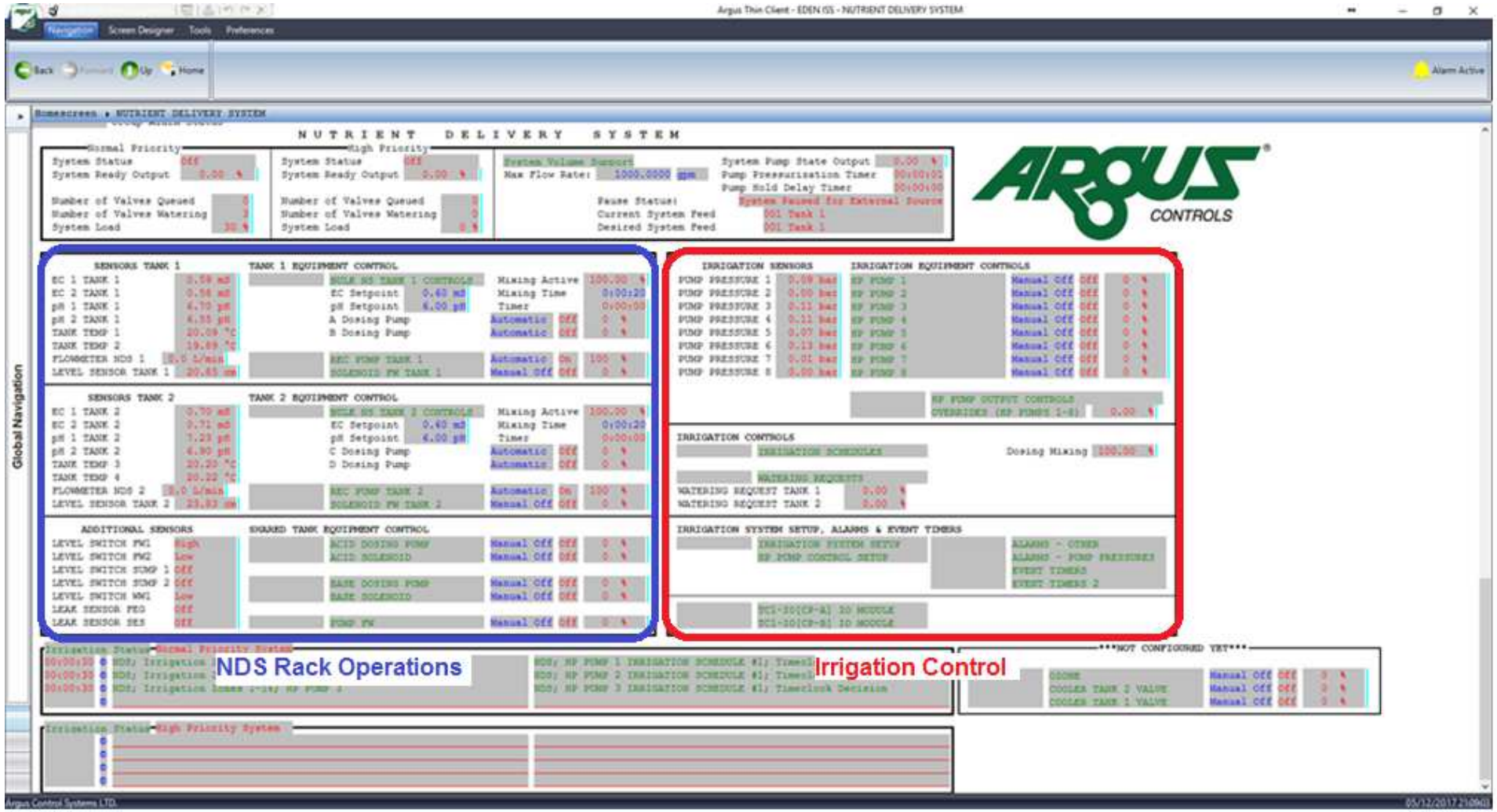


Figure 75: NDS Main Screen

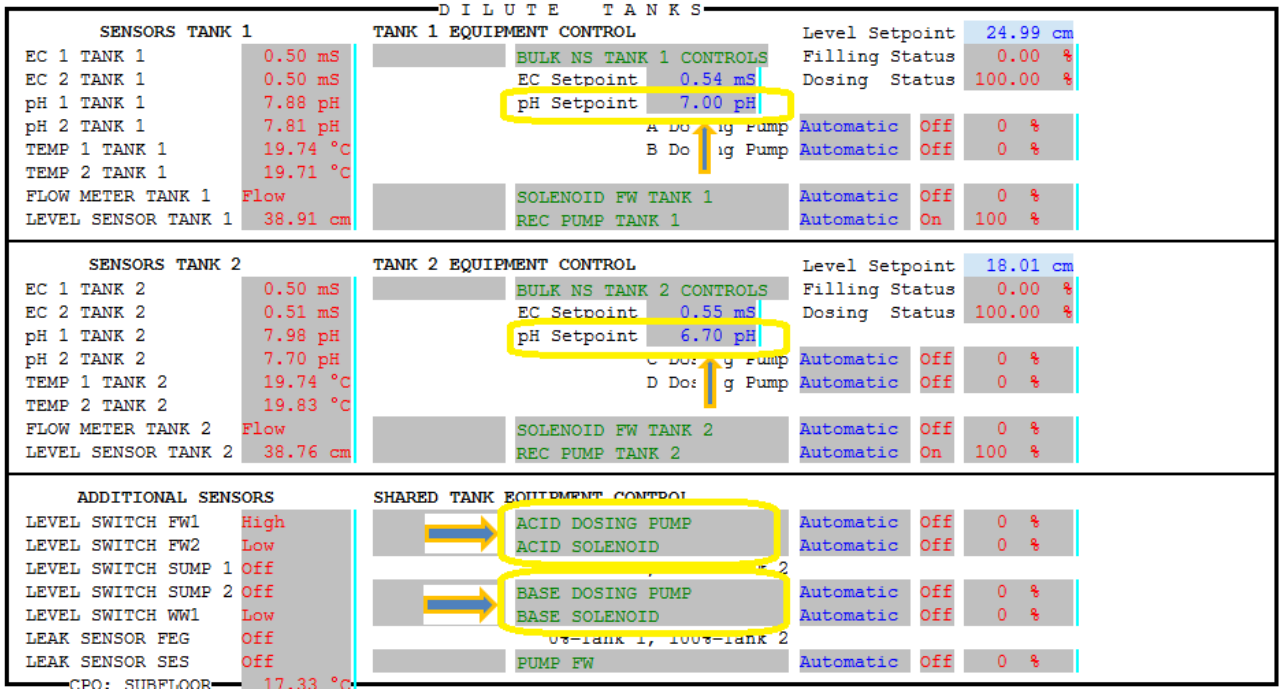


Figure 76: PH Control

pH Probe Calibration

Calibration is performed directly through the pH board using pH calibration standards. Three standards are required for proper calibration of the units and consist of pH 4.0, 7.0 and 10.0 solutions. Starting with the pH 7.0 solution, the procedure is as follows:

1. Remove the probe to be calibrated from the nutrient tank and rinse with deionized (or equivalent)
2. Place the probe in pH 7.0 calibration solution and ensure the end of the probe is completely submerged
3. Press and hold the button marked “7.0” for 1.5 seconds
4. The display will flash: CAL 7.0
5. When completed, the display will flash: done
6. Remove the probe from the calibration solution, rinse with de-ionized water (or equivalent) and return to the nutrient tank or:
7. Repeat this process to calibrate for pH 4.0 and pH 10.0.

EC Control (fig. 77)

Nutrient delivery system EC control setpoints are located on the NDS landing page. To change the EC setpoint value, select the **EC Setpoint** for either tank 1 or tank 2 and enter a new value when prompted by the Argus control system.

To enable EC control for either or both NDS nutrient tanks, the actuators must be set to automatic operation on the NDS landing page. For Nutrient tank 1, change **A Dosing Pump** and **B Dosing Pump** to Automatic. For tank 2, change **C Dosing Pump** and **D Dosing Pump** to Automatic.

Figure 77: EC Control

EC probe Calibration

The conductivity sensor uses a 3 point calibration: dry, low and high.

The first calibration point is “dry” and this is only performed when a new probe is connected to the transmitter for the first time. The other two calibration points are preset to specific industry standard calibration values. To account for possibly higher EC levels, the probes used in the EDEN system are midrange with a calibration constant of K=1.

Setup of the transmitters in the NDS system will have been performed prior to system startup in Antarctica. No changes will need to be made when changing probes unless a probe with a different constant is used. Follow the Atlas Scientific data sheet if this step is to be performed.

The standards required for calibration are 1,413µs and 12,880µs.

Dry calibration (first connection only)

Dry probe calibration is analogous to the tare function on a scale. After dry calibration the displayed conductivity should be 0.

1. If the probe is not dry, dry it off
2. Press and hold the dry calibration button for 1.5 seconds.
3. The screen will display “dry” then "dONE" when completed

Low and high calibration

Low calibration is as follows:

1. Remove the probe from the nutrient tank and rinse with deionized water (or equivalent)
2. Place the probe in the 1,413µs solution – bottom of the probe should be completely submersed
3. Wait until the conductivity readings stabilize
4. Press and hold the low calibration button for 1.5 seconds
5. The screen will display “Low” then "Done" when completed.

Clean the probe and perform the same procedure for high point calibration in the 12,880µs solution.

Mixing of the nutrient solution and nutrient level restoring (fig. 78)

In general, the adequate mixing of the nutrient solution, needed when additional stock solutions are added or the pH has to be adjusted, is obtained by means of the recirculation pumps. In terms of system configuration that is achieved if the REC PUMPTANK 1 and REC PUMP TANK 2 status is set to Automatic (Fig. 73).

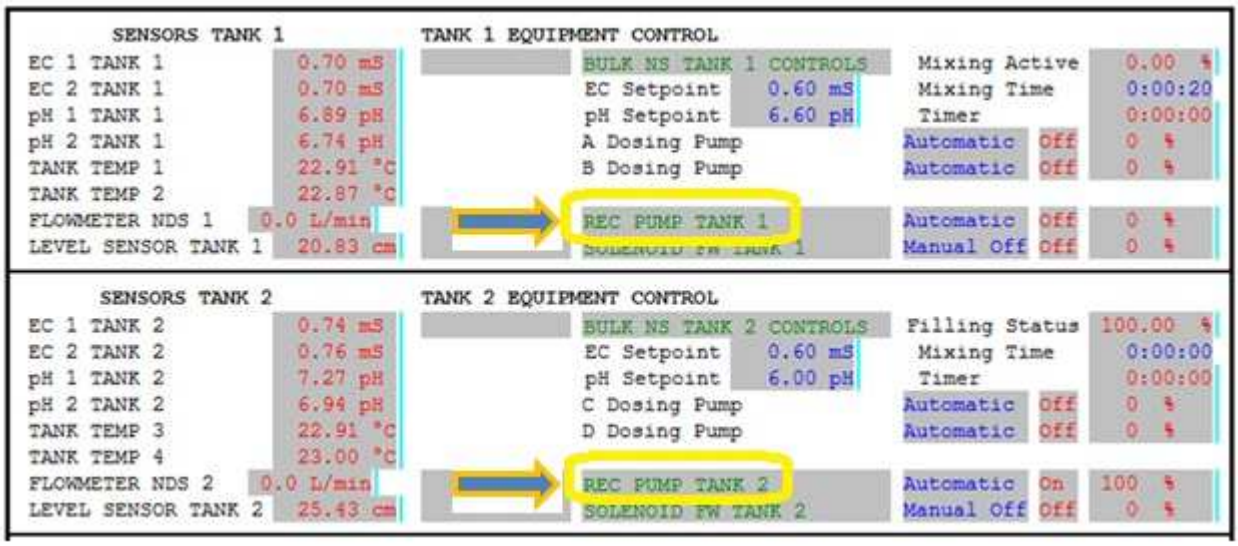


Fig. 78: Mixing the nutrient solution

In the same way, if the level in the nutrient tanks falls below a set threshold, the system is able to pump fresh water from the fresh water tank in the cold porch to the nutrient tanks opening the solenoid valves in response to a level sensor within each tank. To enable the fresh water injection solenoids, the setting for SOLENOID FW TANK 1 and SOLENOID FW TANK 2 have to be set to Automatic.

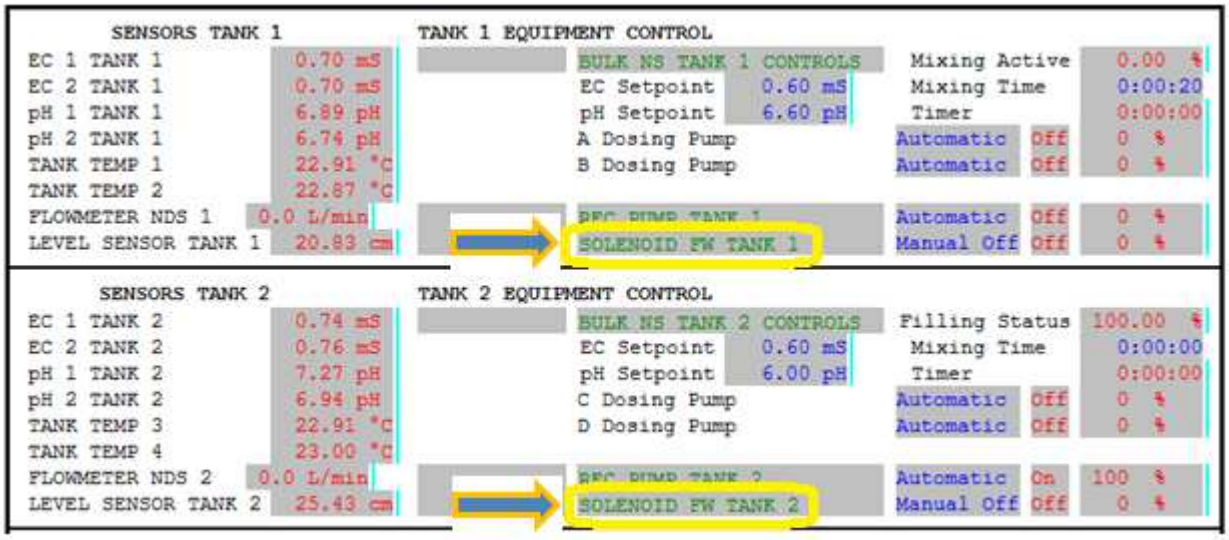


Figure 79: Nutrient tanks refill

Irrigation Control

Each of the eight NDS racks can be set to receive nutrient solution from either TANK 1 or TANK2. To change the source solution, both the feed valve AND the return valve MUST be switched to the appropriate tank. To change the feed valve for any rack, refer to the diagram of valve position (Figure 80).

The corresponding waste valve MUST also be changed. Refer to the valve diagram below for the correct positioning of the valve handle.

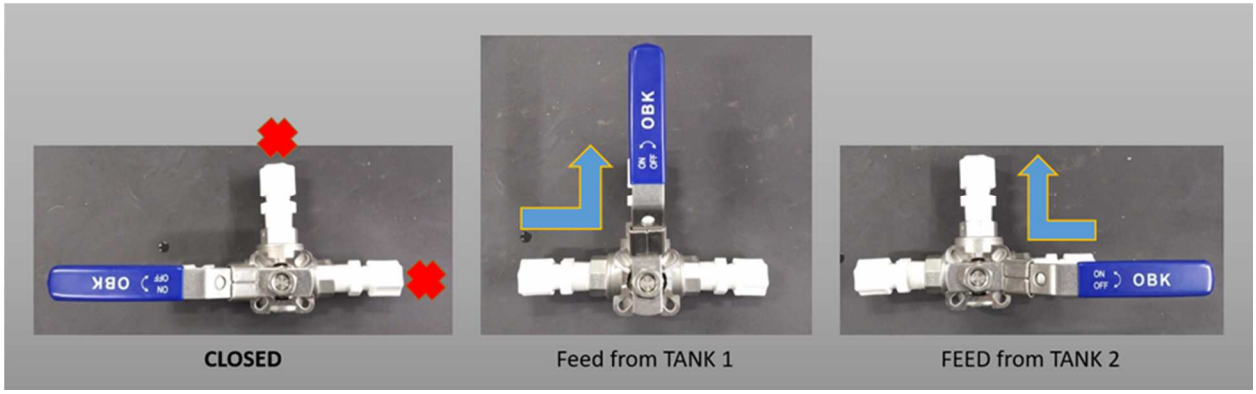


Figure 80. NDS feed tank valve positions

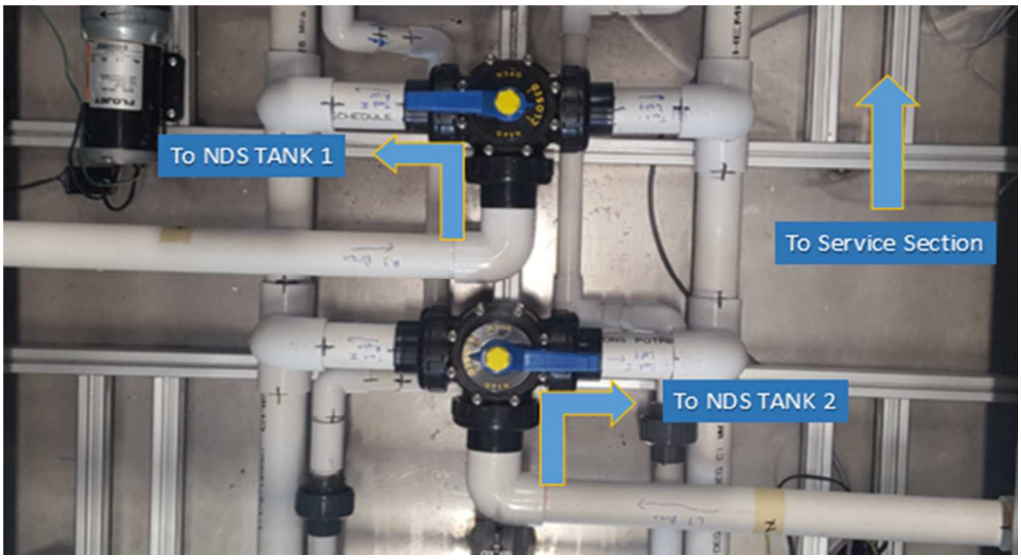


Figure 81: Waste valve positions

Irrigation pump control

Each of the eight NDS growing racks is fed by a single high pressure pump (in this case numbered from 1 to 8) which is connected through a series of pipes to one of the nutrient tanks. Each of the high pressure pumps is operated independently by the control system. To enable, for example, pump 3 (**P3**), that can be done changing HP PUMP 3 from Manual Off to Automatic, on the NDS landing screen.

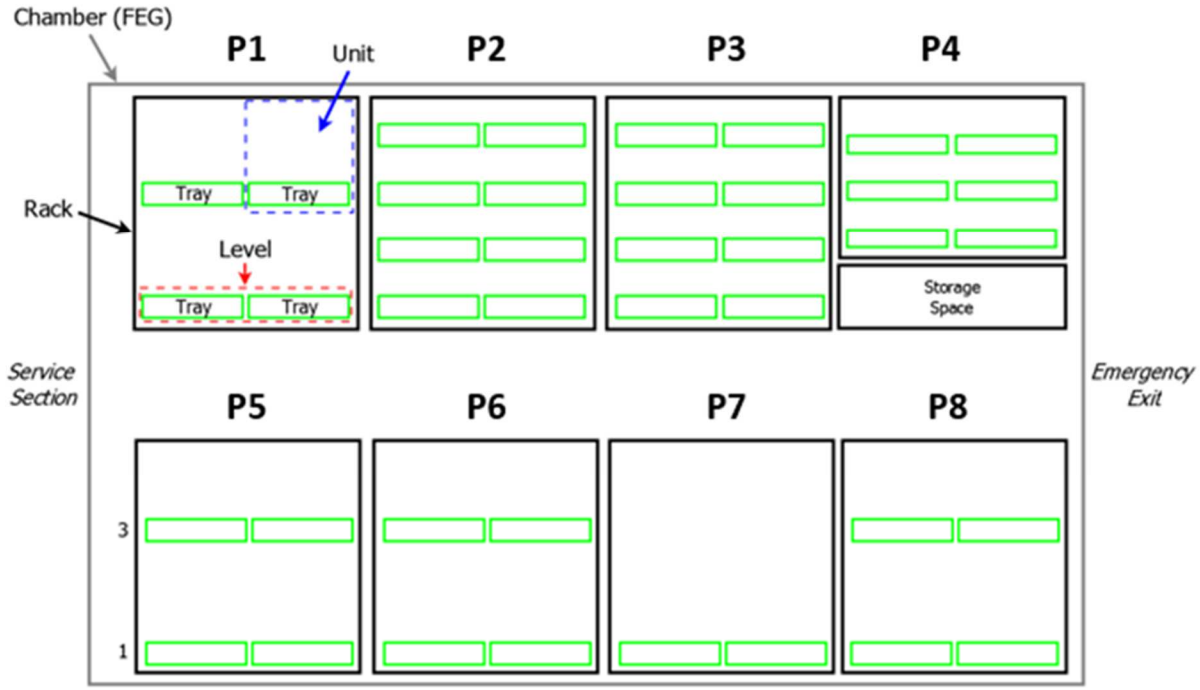


Figure 82. Pump positions with respect to NDS racks in the FEG

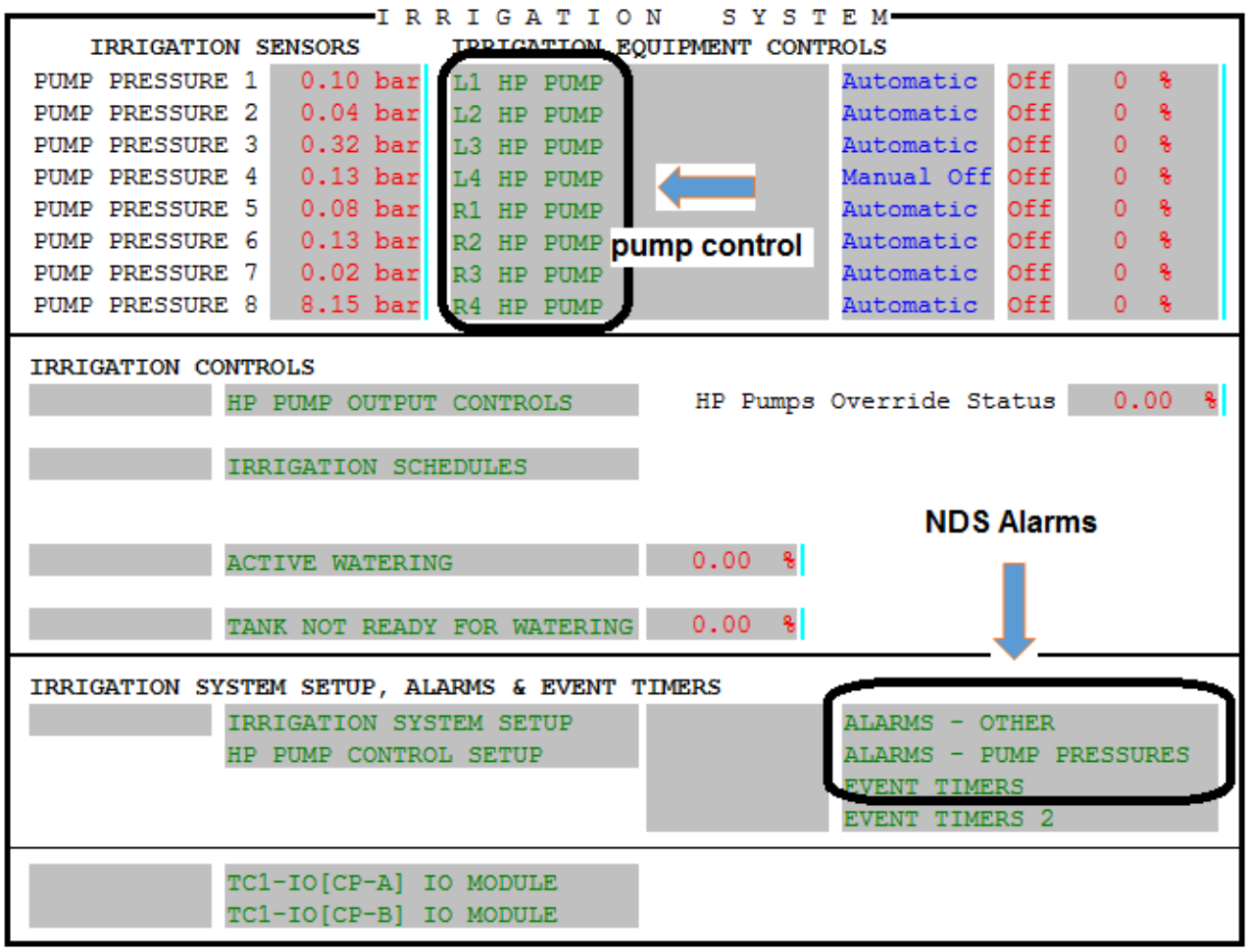


Figure 83 - Irrigation Control

Finally, the system also permit to define an irrigation schedule, i.e. to define the time at which the NDS is feeding the nutrient solution to the plants and to define some alarms that inform the operators on the issues on the critical items, like for example the pumps, or on the irrigations needs.

8.2Plant Cultivation

Plant Cultivation is the main objective of the EDEN ISS project. Several different crops will be cultivated with their specific requirements for optimal growth and production. Due to the limited space in the MTF, all crops will be grown in the single growth compartment of the MTF and thus an 'average climate' is selected that is suitable for all different crops as per the following table 6.

Table 6: Cultivation ambient parameters

	Day	Night
Duration (hours)	17	7
Light intensity ($\mu molm^{-2}s^{-1}$)	300 – 600	0
Temp (°C)	21	19
CO_2 (ppm)	750	750
RH (%)	75	85

As far as the nutrient solution is concerned, in the MTF two nutrient solutions are supplied; a nutrient solution for leafy greens/vegetative crops, and a nutrient solution for fruit bearing crops like tomato, cucumber and pepper as per the following table 7:

Table 7: Nutrient Solution composition

	Dimension	Leafy greens and vegetative phase of crops	Fruit bearing crops
Macro elements			
NH4	mmol L^{-1}	0.9	1.1
K	mmol L^{-1}	7.6	7.3
Na	mmol L^{-1}		
Ca	mmol L^{-1}	3.1	2.9
Mg	mmol L^{-1}	1.0	1.1
NO3	mmol L^{-1}	13.2	11.4
Cl	mmol L^{-1}	0.5	0.5
SO4	mmol L^{-1}	0.8	1.6
HCO3	mmol L^{-1}		
H2PO4	mmol L^{-1}	1.4	1.3
Si	mmol L^{-1}	0.5	
Microelements			
Fe	µmol.L^{-1}	28	25
Mn	µmol.L^{-1}	1.4	10

Zn	µmol.L^{-1}	1.8	4
B	µmol.L^{-1}	21	21
Cu	µmol.L^{-1}	0.5	0.8
Mo	µmol.L^{-1}	0.3	0.5
EC calculated*	mS cm^{-1}	1.8	1.7
EC irrigation**	mS cm^{-1}	2.3	3.5
EC irrigation** - range		2.0 – 2.8	3.0 – 4.0
pH		5.8	5.8

*Calculated EC is based on the concentration of the elements in this Table.
**Irrigation EC is the EC needed for the crops.

The plant cultivation process can be split in different phases coming from the sowing to the food consumption.

8.2.1 Sowing and Germination

Sowing represent the start of a cultivation process. The seeds are sowed and germinated within a reusable growing substrate in the nursery compartment (see figure 84). The seeds are put in the rockwool plugs that are accommodate in the a plastic holder (see fig. 85). One or more seeds (depending on the plant species) are inserted in the rockwool plug by means of tweezers for larger seeds and wooden stick for small seeds. After that, the plastic holder are inserted in a polypropilene (in the nursery compartment) tray filled (manually) with the nutrient solution up to a quarter of its height.

Figure 84: Nursery Compartment

Figure 85: Seeds holder

8.2.2 Thinning and Selection

Thinning is a process necessary to increase the space between the germinated plants in order to improve the light interception. Crew is requested to select the best-germinated plants for the next growth phase and to dispose the weak plants and the ungerminated seeds.

For the selected plants, the thinning process is done of four steps:

1. Remove the rockwool plug and insert it in a plastic plug holder specifically produced for the EDEN ISS project (fig. 80)
2. Insert the plug holder in a dedicated box. This box is provided with holes for nutrient solution and/or water entrance (fig. 81)
3. Put the boxes in another polypropilene tray in the nursery compartment
4. Feed the polypropilene tray with nutrient solution/water by means of the NDS

Figure 86: Step1. Remove the rockwool plug and insert in the plastic plug holders

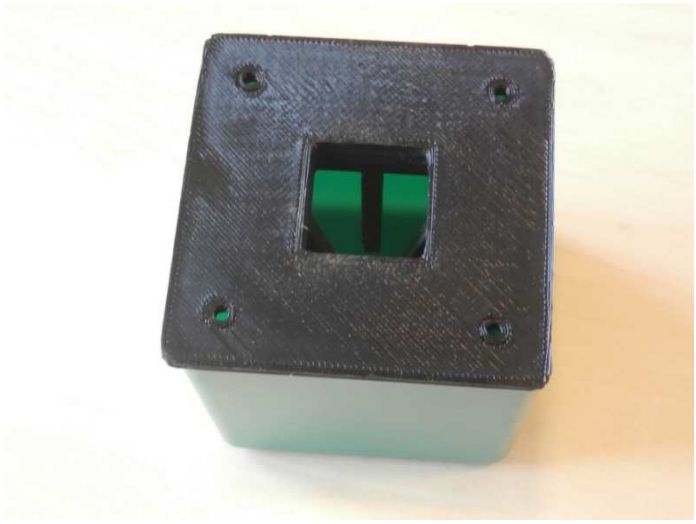


Figure 87: Step2 - Plug holder inserted in the box (in the picture without the rock wool and the germinated seed)

Figure 88: Step 4 - Boxes inserted in the polypropylene tray

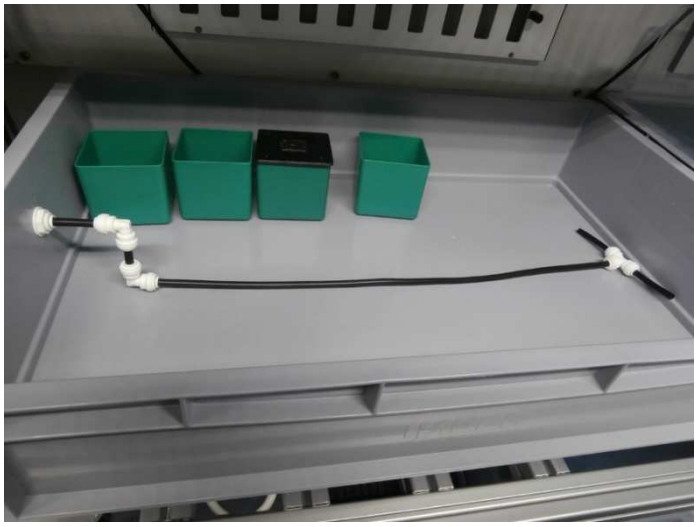


Fig. 89 Irrigation system in the polypropylene tray

8.2.3 Transplant into grow out trays

Once the nursery phase is completed, the plants are transferred into the grow-out positions. Different accommodations are foreseen depending on the plant typology, the difference stands on the only number of holes in the tray lids. As matter of fact the trays are the same for each plant. The following pictures (fig. 90 and fig. 91) show some of the trays available at the moment, the schematics the foreseen lids layout with respect the plant tipology

Figure. 90: Example of tray lids tipology

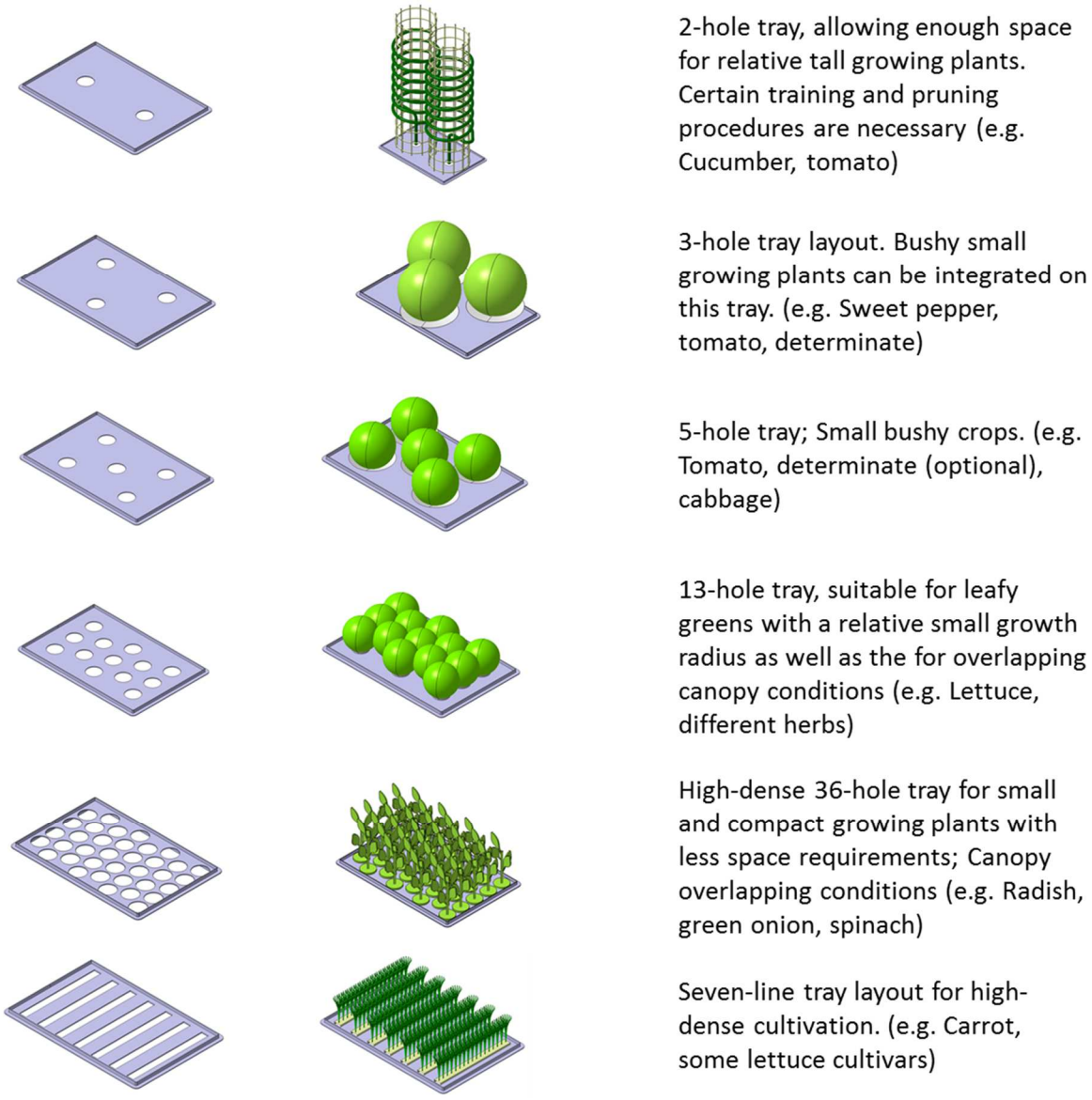


Figure 91: Tray lids vs plant tipology

8.2.4 Plant Growth Monitoring

The fruiting crops (tomato, cucumber and pepper) need additional treatment steps along their production cycle. Once they are planted in their final grow-out position, some crop maintenance cultivation steps need to be performed on a daily or weekly basis. During these maintenance activities, the crew is also requested to check the plant status and to report on any disease symptom for the early definition of medical treatments.

The first work to be done is just a daily check of the plant health and status. The crew is requested to verify that the plants are not affected by any anomaly like spots on leaves or on the stems, and wilting signals. That can be done either looking at the PHM acquired images or via inspection in the FEG.

Figure 92: Example of brown spot on leaf (leaf lesion of Alternaria Solani)

Figure 93: Example of brow spot on tomato stem (Late blight disease lesion)

Figure 94: Example of wilted tomato plant

At any time abnormal appearance is recognized crew is requested to take additional pictures of the plants affected and send them to remote experts for deeper analysis and definition of corrective actions. A wilting signal can led to the manual provision of nutrient solution and/or water. Nevertheless in this case a check of the NDS functionalities has to be done.

The second work step is pruning and training, to be done as necessary.

Training, especially in cucumber, tomato, and pepper, is the term for the procedure of shaping the plant into a desired optimal growth architecture, providing at the same time a support to sustain the plant themselves. Light interception and air movement for gas exchange for the crops is improved. In greenhouse production, tomato and cucumber are normally trained with wires (figure 95) to enhance the area of light interception, and to display the fruit for ease of harvest, nevertheless a tool to sustain the lower plant of the main plant stem is envisaged in the EDEN ISS cultivation of plants like tomatoes, pepper and cucumber (Figure 96).

As far as the wires management is concerned, the main idea is to implement hooks in the rack structure, mainly around the LED lamps, where the wires will be attached.

Figure 95: Plant training

Figure 96: Plant Main Stem Support

Plant pruning is aimed at the removal of leaves and/or lateral shot (also called sucker) in order to increase the air circulation and/or light interception and to optimize the nutrient distribution to the plants. This methodology applies to the fruiting crops (tomatoes, cucumber and pepper). The fig. 97 shows an entire life cycle of a sucker on a tomato plant.

Figure 97: Sucker life cycle

Finally a third work step has to be considered for plant cultivation in a greenhouse, the so called pollination. A successful pollination depends on environmental factors such as temperature, water status, humidity, nutrient supply, and pollen transfer. Active pollination is a procedure to aid the transfer of pollen from the anthers to the stigma of the flower and has to be considered when the natural pollination is insufficient. That is the case of closed environment like that of EDEN ISS. This procedure involves pollination by hand with the use of a brush or a similar tool, like professional vibrators or air-blast sprayers, which are often used within commercial greenhouses. Two plants typology of EDEN ISS are affected: tomatoes and peppers. The pollination will be done by means of a vibrator as shown in fig. 99 and fig. 99. In principle, the crew is requested to perform the pollination activity every day as each new flowers open, but of course adverse conditions could prevent that. Should be this the case, the activity has to be resumed as soon as possible to promote the fruits generation.

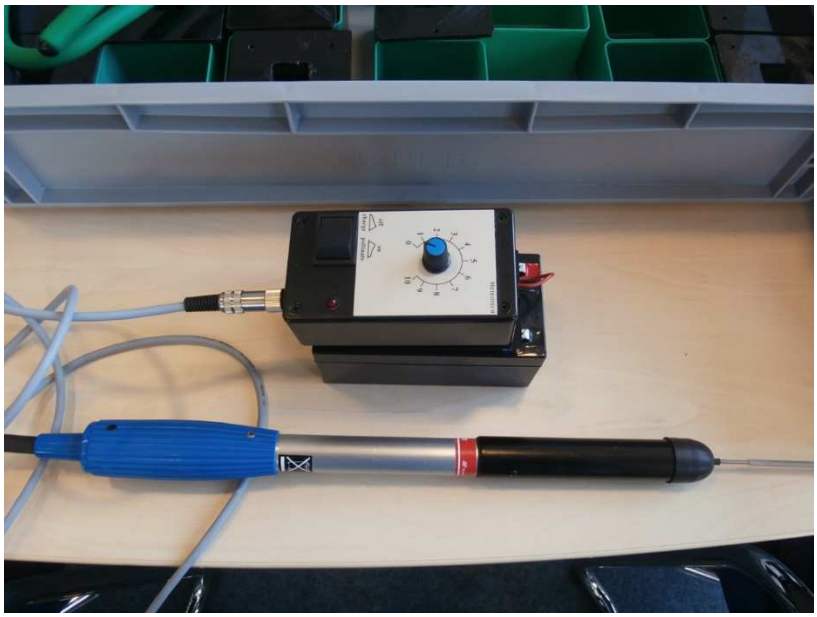


Figure 98: Vibrator for active pollination

Figure 99: Pollination by means of a vibrator

8.2.5 Harvesting

Two different approaches have to be considered for harvesting:

- Single point harvesting event (Vegetative crops, like Leafy greens and radish)
- Multiple harvesting events (lettuce, herbs, tomatoes, pepper and cucumber)

For vegetative crops, a single point harvest takes place at the end of the production cycle. The tray, filled with 100% mature plants, is removed from the grow position and transferred to the pre-and post-processing area. The cultivation position is then again available for a new tray. Leafy greens can be harvested and eaten after 4 to 6 weeks after plant transplanting (fig.100), while radish can be harvested and eaten after 3 weeks after sowing (fig. 101). At this stage the expected taproot diameter should be in the range 20-35 mm

Figure 100: Leafy Green Harvested. From the left: Swiss Chard, Rockets and Red Mustard)

Figure 101: Radish ready for harvesting

For fruiting crops (and herbs) multiple selective harvests will be performed. Here, the crewmember needs to examine each plant and evaluate which fruit can be harvested and which fruit shall be left for further development.

Chives can be harvested 6 weeks after sowing as per fig. 102. Chives can be totally harvested; plants will regrow very easily and can be harvested again after 4 weeks. This can be repeated at least 3 times and probably more.

Figure 102: Chives harvesting

Parsley harvesting can start when the plant is approximately 15 cm height – 4 weeks of plant development. The harvesting should be done on the only mature leaf, i.e. that the youngest leaf shall not cut off, since this growing point will grow very easily and can be harvested again after 4 weeks. This can be repeated at least 3 times and probably more.

Figure 103: Parsley Harvesting

Basil can be harvested as soon as the plant reaches about 20 cm in height, and in any case before the plants start to bud and the flowers start to bloom (also known as "bolting"). As for parsley the basil harvesting shall ensure that young leaf are left on the plant for another growth and harvesting cycle (fig. 104 and fig. 105)

Fig.104: Basil Harvesting

Figure 105: Basil plant after harvesting

Lettuce Spread harvest can commence 4 weeks after sowing at the moment that the plants touch each other and maximum soil cover is reached. The outer (1-3) leaves can be harvested from each plant and be eaten. Spread harvest can be carried out once or twice weekly until plants start to bolt for another 7 weeks

Figure 106: Cutting the lettuce leaves

Dwarf Tomato can be harvested starting from 12 weeks after sowing (depends on the cultivation temperature! Is possible when grown at 25C). The perfect tomato for picking will be firm and red (if we are cultivating red tomato) regardless of size, with perhaps some yellow remaining around the stem. A ripe tomato will be only slightly soft. Tomatoes shall be harvested individually.

Figure 107: Tomatoes ready for harvesting

Pepper grows very slowly and it takes about 4 months to harvest the first fruits. Bell peppers grow in a range of colors, including green, red, dark purple, yellow and orange. In general, they are ready to harvest when they are the full color of the variety planted. Picking peppers before they are fully mature will encourage the plant to produce more flowers and, thus, more peppers.

Figure 108: Peppers harvesting using scissors

Cucumbers need a long growing season and are ready for harvest in 50 to 70 days. The fruits ripen at different times on the vine, so it is essential to pick them as they are ready. Cucumber should be harvested when the final size has been reached, which is around 10 cm long (around 60 grams). Cucumbers must be picked before they show the first signs of yellowing, which indicate the fruits are past their prime.

Figure 109: Cucumber harvesting using garden shears

8.2.6 Food sanitization for consumption

The need for food sanitization before consumption is aimed at minimizing as much as possible any risk of sickness due to microbial contamination of plant food produced in the FEG. For this reason it is planned to sanitize all produce before consumption. The methodology depends on the crop type, in particular:

- using commercial hypochlorite solution to sanitize **non-leafy** vegetables by immersion and washing prior to consume by the NM-III crew
- Using sodium bicarbonate will be use instead of hypochlorite in the case of **leafy** vegetables

8.3 Food Safety and Quality Analysis

One of the aims of the EDEN ISS project is to assess the nutritional and organoleptic quality and safety of the plants produced in the greenhouse. This is a crucial step forward with respect to plant food production in space because it could allow future space growers to optimize the growing environment to maximize the production of key dietary nutrients required rather than growing only to maximize biomass.

The definition of the species to be cultivated and of the quality attributes to be measured on them in EDEN ISS, have been done taking into account the constraints and the limitations of the Antarctic working environment and of the competences of Antarctica operator. As matter of fact, even if the NM-III station has space for a laboratory, it is not possible to equip it with all the necessary instruments for quality and safety analysis. Morover the lack of competences of the EDEN ISS operator it has to be considered. For example the chemical analysis cannot be done without the needed instruments and skills.

For that reason only a limited number of activities will be possible at NMIII, the others will be conducted in the laboratory of CNR and LIT when the samples will be back to Europe.

8.3.1 On site Quality Analysis

As on-site simple quality parameters measurement, the crewmember will be using simple instruments such as:

- **Refractometer**
- **Penetrometer**
- **Colourimeter**
- **Clorophyllmeter**
- **Nitrate Ion Meter**

In the following lines their description and for what they are used.

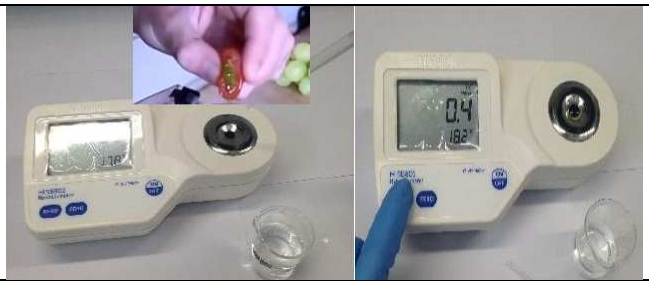
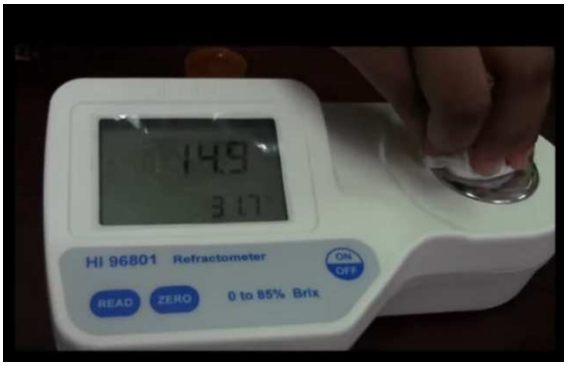
Refractomer

The Refractometer is a tool that measure the percent solids (TSS) in a given weight of plant juice (also called BRIX). The BRIX is actually a summation of the pounds of sucrose, fructose, vitamins, minerals, amino acids, proteins, hormones, and other solids in one hundred pounds of any particular plant juice. BRIX varies directly with plant **QUALITY**, for this reason the refractometer will be used in the EDEN ISS operations.

Figure . 110: HANNA HI 96801 Refractometer

The **HANNA HI 96801 Refractometer** has been selected for the EDEN ISS operations (fig. 110). Its usage is very straightforward as shown in the following lines:

Step 1: Calibration - Using a plastic pipette, fill the sample well with distilled or deionized water. Make sure the prism is completely covered. - Cover the sample well with your hand or other shading plate during the calibration - Press the zero key. If no error messages appears, the unit is calibrated. The zero will be set on the display and will reamin until the uniti s deactivated - Using a soft tissue, remove the water and dry the surface	

Note: Calibration has to be done every day before starting with the measurement, or after a long series of measurements.	
Step 2: Measurement - Squeeze juice out on the sample well - Press the read key - Take the reading Note: the juice squeezing can be done by hand but even better using a garlic squeezer	
Step 3: Sample well cleaning - Remove sample from the sample well by absorbing with a soft tissue. - Using a plastic pipette, rinse prism and sample well with distilled or deionized water. Wipe dry. The instrument is ready for the next sample. Note: Some operators are used to calibrate the instrument between the single measurements	

The following table 8 provides indication on the expected values for some of the species cultivated in the FEG.

Table 8: expected values

Produce	Avg %Brix
Rocket	4.57
Lettuce	1.47
Pepper (Green) (3gFW)	4.63
Pepper (Red) (3gFW)	4.83
Salad Tomato	4
Small Cherry	7.6
large Cherry	5.8

Hand-held Penetrometer: The Penetrometer is and hand-held device used to measure the firmness of relatively homogenous fruit and/or vegetables. In the EDEN ISS operations it will be used for the quality analysis of the cucumbers, tomatoes and peppers. The **PCE Instruments Force Gauge PCE-FM 200** (fig. 111) has been selected for the EDEN ISS operations.

Figure 111: PCE Instruments Force Gauge PCE-FM 200

Several sensing head can be mounted on the instrument (the picture shows the hook head mounted on the instrument for tension measurement), for the EDEN ISS the only conic head has to considered. The penetrometer operations are straightforward. Once the conic head has been mounted and the instruments has been activated, the cone portion of the probe has to be inserted into the sample with a constant motion. The reading can be taken when the action has been terminated. The following pictures provide an indication of the penetrometer operations and the expected values for some of the EDEN ISS crops.

Produce	Avg g/oz/N	Std Dev	95% CI
Baby Vine Tomatoes, N=12 x 2 reps	0.74	0.12	0.002
Baby Vine Plum Tomatoes, N=14 x 2 reps	0.89	0.07	0.001
Large Vine Tomatoes, N=5 x 3 reps	1.15	0.12	0.003
Salad Tomatoes, N=4 x 3 reps	1.82	0.05	0.001
Green Bell Pepper, N=3 x 4 reps	2.18	0.25	0.009
Yellow Bell Pepper, N=3 x 4 reps	2.02	0.05	0.002
Red Bell Pepper, N=3 x 4 reps	1.56	0.10	0.004
Cucumber, N=3 x 6 reps	2.17	0.08	0.003
Strawberries, N=18 x 2 reps	0.24	0.05	0.001

Figure 112: Penetrometer operation and expected value

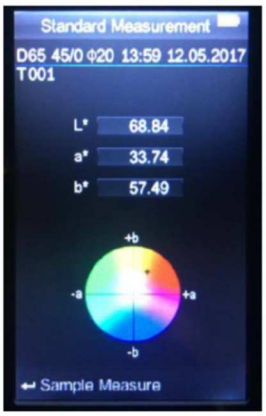
Hand-held Colorimeter: is a tool for the measurement of the colour co-ordinates of food samples as an indication of the bioactive content. In the EDEN ISS program this instrument will only be used on larger fruits and vegetables such as tomatoes (including baby tomatoes), bell pepper, cucumbers.
The instruments reads three parameters, the so called CIE system coordinates (L*, a*, b*):

- a* takes positive values for reddish colours and negative values for the greenish ones
- b* takes positive values for yellowish colours and negative values for the bluish ones
- L* is an approximate measurement of luminosity.

For the EDEN ISS operations the **PCE Instruments Colourimeter PCE-CSM 1** has been selected (fig. 113)

Figure 113: PCE Instruments Colourimeter PCE-CSM 1

This instrument has to be calibrated before the operations, but in principle it does not require continuous calibrations once that has been done, unless there are big changes in the environment conditions, or the instrument is not used for long time. The operations consist in two main steps:

Step1: Taking standard measurement Turn on the device and remove the black cap, the "Standard Measurement" screen appears. To take a measurement, follow these steps: 1. Press and hold the testing button – located on the back panel of the device. Four (4) light cones appear to aid with selecting the measuring point. 2. Move the device as close to the measuring point as possible. 3. Release the testing button. The colorimeter now takes a measurement. Note: The standard measurement allows for clear identification of strong red, yellow and green colours. This can then be used to determine colour change in fruits and vegetables as they grow. Standard colour measurements are provided below for comparison purposes.	 

Step 2: Sample measurement 1. When in the result screen of a standard measurement, press the Enter button . The “Sample Measurement” display appears. 2. Take another measurement (same process as the standard measurement). 3. The deviation of the sample will appear in a display similar to hat on the side.	

Chlorophyll SPAD Meter: The SPAD Meter meter is a hand-held device that is used for the rapid, accurate and non-destructive measurement of leaf chlorophyll concentrations. Chlorophyll content is one indicator of plant health, and can be used to optimize the timing and quantity of applying additional fertilizer to provide larger crop yields of higher quality with lower environmental load. For the EDEN ISS operations, the **MINOLTA Chlorophyll Meter SPAD-502** has been selected.

Figure 114: Chlorophyll SPAD Meter

The use of the instrument is quite straightforward as shown in figure 115. The operator has just to insert the sample to be measured into the sample slot of the measuring head, and take the measurement.

The procedure foresee a calibration of the instrument after all the activations, nevertheless this operation is very simple, it is just matter to take a measurement without any sample in the slot of the measurement head, before starting with real measurements. The following table shows the expected SPAD Chlorophyll values for produce sampled at multiple locations.

Figure 115: Use of the Chlorophyll SPAD Meter

Table9: Spad Meter expected readings

Produce	Avg Reading	Std Dev	95% CI
Red Lettuce (Outrageous) Inner Green Leaf N=12	5.98	1.99	0.04
Red Lettuce (Outrageous) Outer Red Leaf N=12	29.33	7.25	0.13
Butterleaf Lettuce (Red Variety) Inner Green Leaf, N=10	3.79	2.50	0.05
Butterleaf Lettuce (Red Variety) Outer Red Leaf, N=10	36.08	10.52	0.21
Chives (leaf Bottom), N=6	34.13	8.77	0.22
Chives (leaf Middle), N=6	39.48	9.86	0.25
Chives (leaf Top), N=6	31.18	8.55	0.11
Parsley (Leaf), N=7	29.80	19.22	0.46
Parsley (Top of Stalk), N=7	15.43	7.79	0.18
Parsley (Bottom of Stalk), N=7	11.36	4.86	0.05

Nitrate Ion Meter is a tool for the evaluation of Nitrate concentration in the harvested samples. Leafy vegetables occupy a very important place in the human diet, but unfortunately constitute a group of foods that contributes maximally to nitrate consumption by living beings. Under excessive application of nitrogen fertilizer, these vegetables can accumulate high levels of nitrate and, upon being consumed by living beings, pose serious health hazards. Therefore, efforts are warranted to check if the nitrate concentration in harvested vegetables are within the allowed range for ingestion by human beings.

The **Horiba Nitrate Ion Meter B-741** has been selected for the EDEN ISS operations. It is a hand-held meters for quick measurements of nitrate ions using a selective membrane and it work with the smallest of samples.

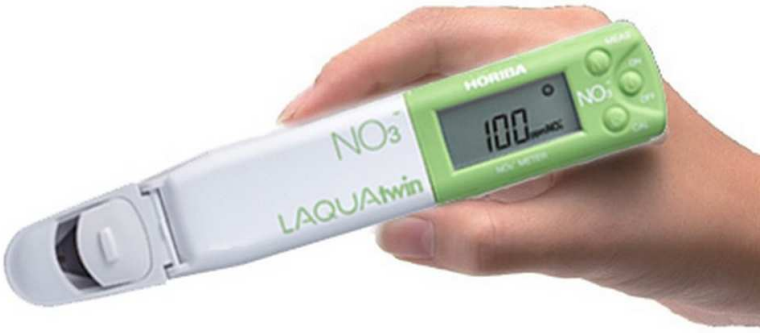


Figure 116: Horiba Nitrate Ion Meter B-741

The measurement start with sample preparation. The harvested leaves or fruits have to be cut in small pieces, then put in a baker and then reduced in even smaller pieces by means of a laboratory spatula. After that, 1g of sample has to be mixed with 5ml of deionized water for ten minutes. When the 10 minutes have expired the sample is ready for measurement. That is done by simply putting the sample on the sensor (enough quantity to completely cover it) and then closing the cover. After the measurement, the sensor has to be washed with deionized water.

Figure 117: Taking measurement

Remark: The sample preparation is very similar to the one described for the on-site safety analysis, therefore the measurement with the Nitrate Ion meter could be combined with the safety measurement.

The instrument has to be calibrated before any measurement session. The calibration is a very simple operation and is done using a standard solution. It is just matter to take a measurement with some drop of the standard solution on the sensor.

Organoleptic Survey

An Organoleptic Crew Surveys can also be performed on site. On that respect, some sample will be harvested, prepared and then tested by the operator that will evaluate the acceptability of each product as per the hedonic acceptability scale (Fig. 118). Following for each food type the crew will assess each sample in order of aroma, appearance, texture and taste. Each sample is scored between 1 and 9 for each of the descriptors on a test sheet with printed scales and place an X on the scale to rank the sample. All sensory results are transferred to an Excel worksheet, the means and standard deviations are calculated and a spider chart generated.

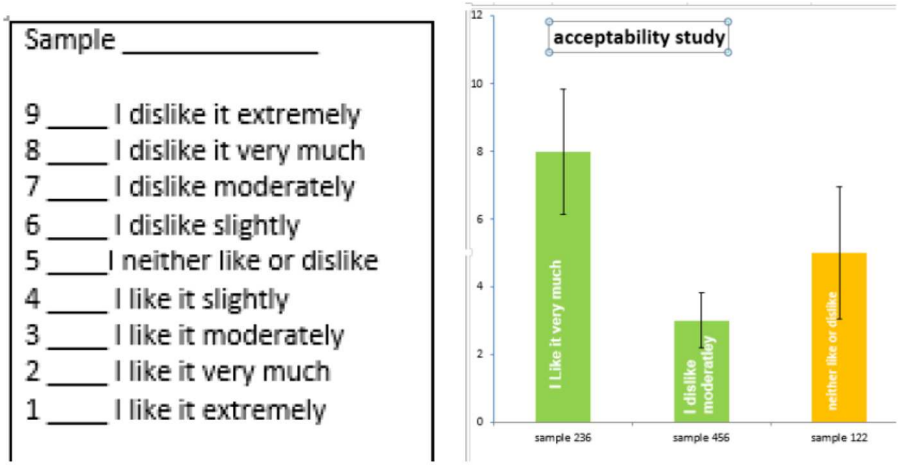


Figure 118: Acceptability Scale

Descriptor	Mean ± Std Dev (N=3)
Colour intensity	4.8 ±0.36
Aroma	3.3 ±0.43
Hardness (on bite)	4.2 ±0.79
Juiciness (on chew)	5.5 ±0.22
Leathery skin (after, residual)	4.6 ±1.23
Sourness	4.4 ±0.44
Sweetness	4.3 ±0.16

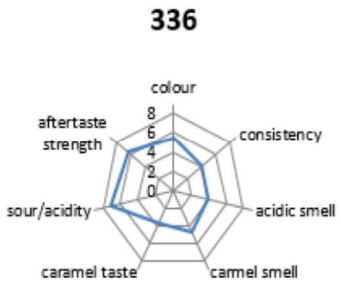


Figure 119: Sensory Evaluation Result

8.3.2 Post Mission Quality Analysis

For the analysis to be performed at CNR and LIT laboratories, a crucial activity to be performed by the Antarctica operator is the sample preparation and storage. That in principle will require a freeze-drying operations on the sample to be sent to Europe or the storage of fresh materials at -20degC. As a preliminary estimate, it is assumed that 100 g of fresh material should be sufficient to perform all analysis, taking into consideration that the dry matter content of the tissues we will be working on is normally close to 5%. Collecting 100g of fresh material should provide approximately 5g of dry matter.

The scheme of plant sampling is in principle the same (with some slight differences) for the three for the three different species to be analyzed:

- edible leaves
- edible fruits
- edible tap roots

In fact for each species the following sampling has to be done:

- Number of sampling: 3 different samplings (3 different leaves, fruits and/or roots)

- Number of replications: 4 (4 independent samples obtained from 4 separate harvests).

leading to a total of 12 samples for each species. Only in the case of the Lactuca sativa L., in addition to the leaves, 1 sampling of the roots will be carried out collecting 5 replicates of plant material.

For each sample two SUB-Samples will be prepared:

- The SUB-Sample 1 of 20 g is stored at -20°C and will be used for the analysis of metabolites as ascorbic acid or pigments (carotenoids, xanthophyll, chlorophylls), that are not preserved at high temperature.
- The SUB-Sample 2 of 80 g is stored at -20°C and then placed on the freeze-dryer to have a sample stabilized through lyophilization. This sample can be used for all measurements on the dry weight basis (cell wall component, nonstructural carbohydrate, organic acid, inorganic anions).

Several tools are required for the sampling activities as listed below and shown in fig.120.

- gloves,
- scalpels,
- scissor,
- kitchen knife,
- absorbent paper,
- falcon tubes,
- aluminum or plastics bags
- weight scale,
- laboratory book,
- permanent black marker

Figure 120: Some of the tools required for sampling

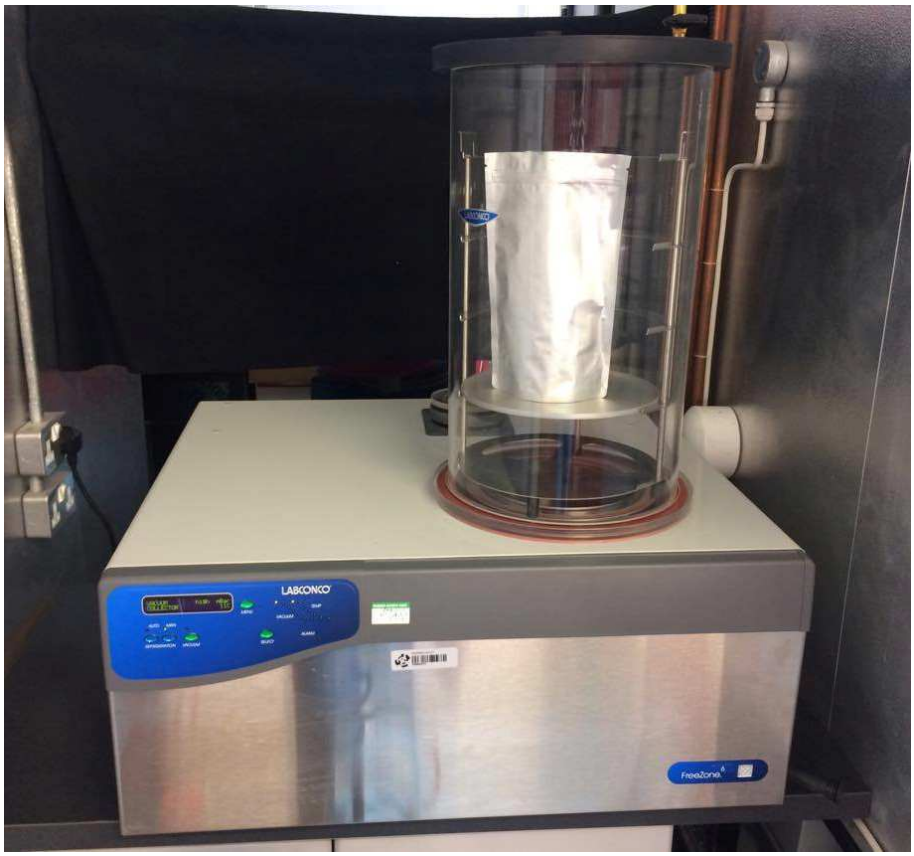


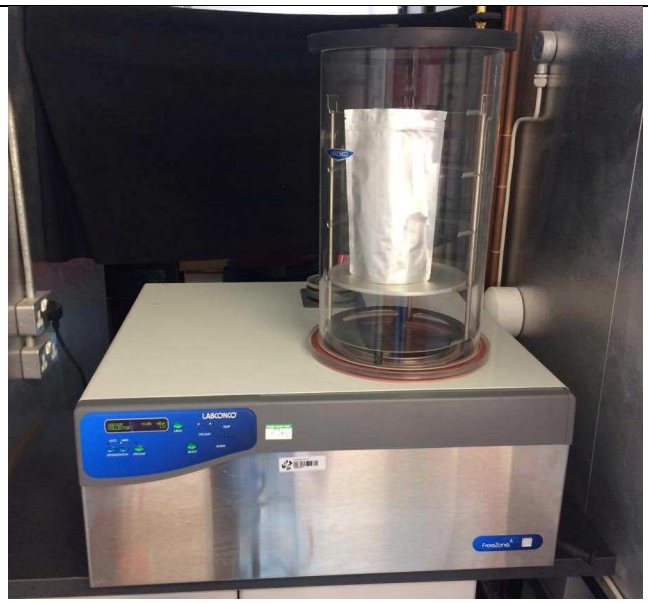
Figure 121: Lyophilizer - FreeZone 6 Liter Benchtop Freeze Dry System

It is worth to underline that the sampling for quality analysis it is not necessary to use sterile tools, therefore no sterilization activities are required before starting the operations. Nevertheless as general recommendation it is required to operate with washed hand and with clean tools.

The sample preparation is similar for all the vegetables and is done of the following steps (described below for the cucumber):

Step 1: Label the bags (alternatively it is possible to use the Falcon tubes) using a permanent black marker	

Step 2: Weigh the bag and annotate its weight on the laboratory book (to have the tare value)	
Step 3: The part of vegetable fruit is cut in small pieces.	
Step 4: Take 100 g of the cut fruit and distribute it in two separate bags labelled SUB1 (20 g) and SUB 2 (80 g). Annotate the weight on the laboratory book.	

Step 5: Store the two bags at -20degC. Make some small holes in the SUB2 Bag before storing it.	
Step 6: When the SUB2 Bag is frozen, take it from the freezer and put it on the freeze- dryer for lyophilization. Note: lyophilization process take approximately 5 day. During this period, the operator has to monitor the decreasing weight until it is stable.	

8.3.3 On site Safety Analysis

Some analysis's will be performed on site with the aim to monitor the following microorganisms per crop type:

- Common pathogens
- Total microbial count
- Yeasts and moulds
- Total Coliform
- *Escherichia coli*
- *Salmonelle spp.*
- *Staphylococcus aureus*
- *Bacillus cereus*
- *Emerging Pathogens*
- *Enterobacter sakazakii*
- *Listeria innocua*
- *Clostridium spp*

Those analyses' requires the availability of several items and tools that have to be made available to the crewmember, with in addition the appropriate procedures to use them.

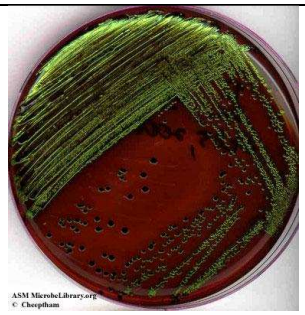
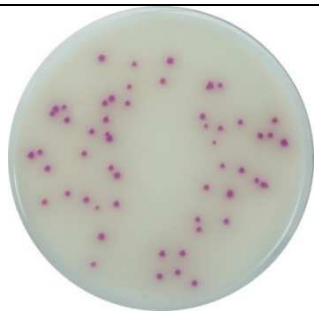
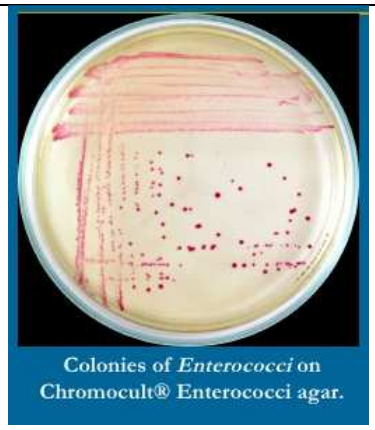
The first items to be considered are the media for the growth, isolation and detection of microorganisms potentially present in fruit and vegetables cultivated in the FEG. They are provided as ready to use plates or vials containing respectively gel and liquid media growth (Fig. 114).

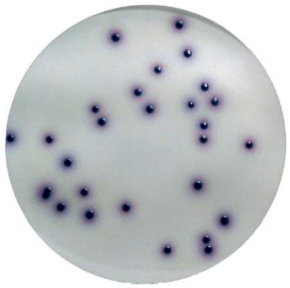
Plate **Vial**

Figure 122: Microorganism growth medium

The usage of plates is straightforward. The methods is based on the analysis of the plates after some hours from the distribution in the plates of few ml of liquid sample prepared by the operator. A positive results is identified by a proliferation of microorganism colonies with well know colours.

The following table provides the list of plates to be used for the on site Safety Analysis during the EDEN ISS operations, with some example on the colonies appearance in terms of colour changes.

Growth Media (Plates)	Microorganism/Colours	Example
EOSIN Methylene Blu Agar (EMB)	Escherechia Coli/Metallic Sheen colonies Salmonella/Colourless colonies	
COLOREX Salmonella Plus	Salmonella enterica /Mauve conies Salmonella typhimurium /Mauve colonies Escherichia coli / Colourless colonies Citrobacter freundii /Blue Colonies	
Chromocult® Entero-cocci Agar	Enterococcus faecalis / dark red colonies Enterococcus faecium / dark red colonies	
Cetrimide Agar	Pseudomonas aeruginosa / Green-yellow-ish to dark green colonies	

CCA COLIFORMS CHRO-MOGENIC AGAR	Escherichia coli /Purple Citrobacter freundii /Magenta	

The methodology that is using the Vials is also known as the Micro Biological Survey (MBS) method, which is an innovative rapid colorimetric system to perform microbiological tests on food, water and surfaces. The method of analysis is based on the observation of the change of color in the suspension formed in the analysis vial used when the test sample is added: similarly to the plates, the suspension changes color if there are microorganisms, the greater the amount of microorganisms, the more rapid the change of color. For EDEN ISS the selected reagents for the selective search of the following microorganisms are:

- CBT-A01 (TOTAL VIABLE COUNT)
- CO-A02 (COLIFORMS)
- EC –A22 (ESCHERICHIA COLI)
- SL-A06 (SALMONELLA SPP.)
- LY-A07 (LISTERIA SPP.)

8.3.3.a Ready to use plate Procedure

The following procedure shows how to prepare the samples for the plates:

Items needed:

- Pipets
- Pipetter
- Adjustable Volume Pipetter
- Pipetter Tips
- Microbial Plates
- Spatulas
- Falcon Conical Tubes (50 ml)
- Falcon Conical Tubes (15 ml)
- Filter Bags
- Scale: A scale is necessary to weight the samples and correctly dimension the culture media in terms of quantity to be used/prepared.
- Microbiological Incubator. In general a laboratory incubators provide a controlled, contaminant-free environment for safe, reliable work with cell and tissue cultures by regulating conditions such as temperature, humidity, and CO2. Microbiological incubators are used for the growth and storage of bacterial cultures and therefore it is the equipment were the prepared samples will be stored for the time necessary for microorganism culture (if any). NMIII is equipped with an incubator, but the possibility to acquire a new one is under discussion.

Figure 123 shows the consumable items to be used, but apart them other tools are required as listed below:

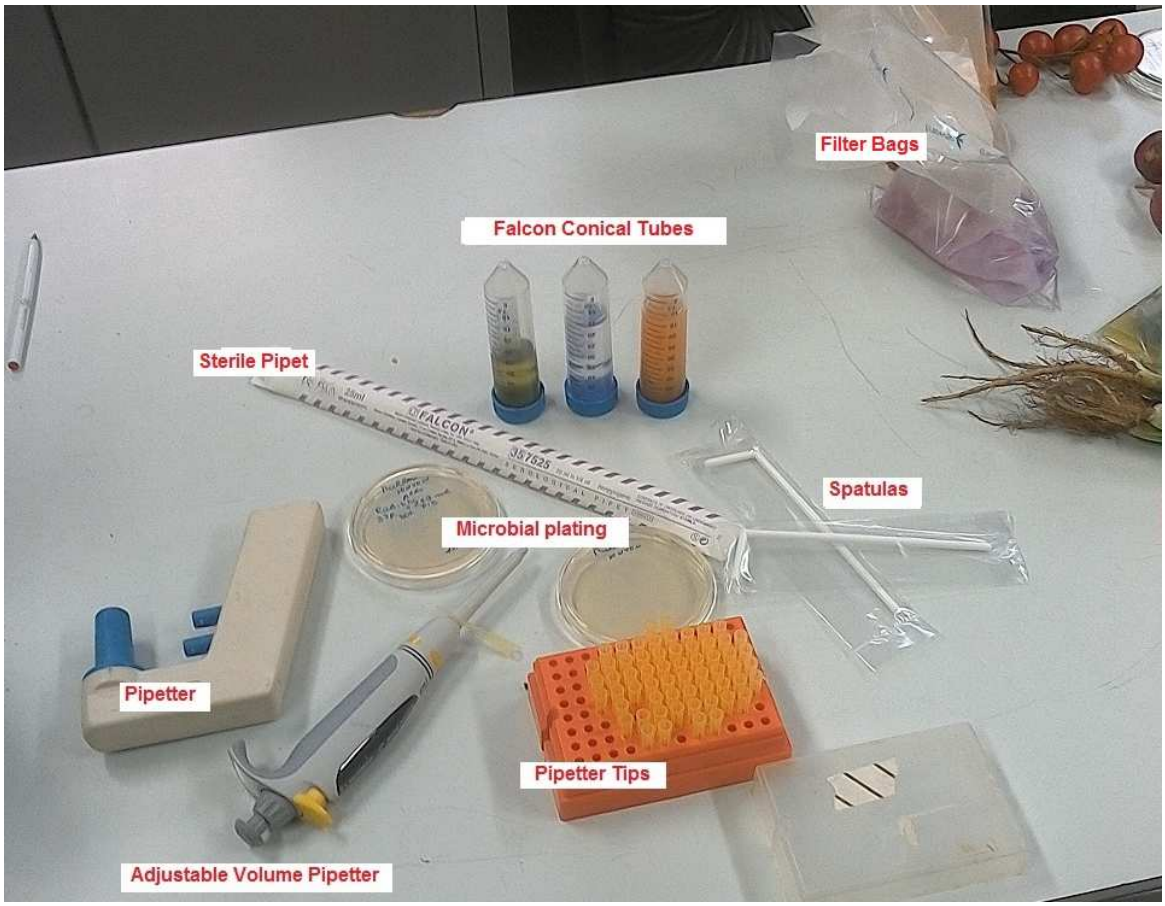


Figure 123: Some of the items required for sample preparation

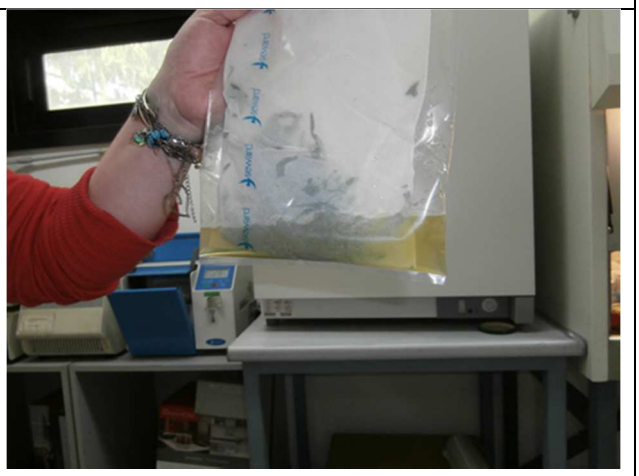
Scale **Incubator**

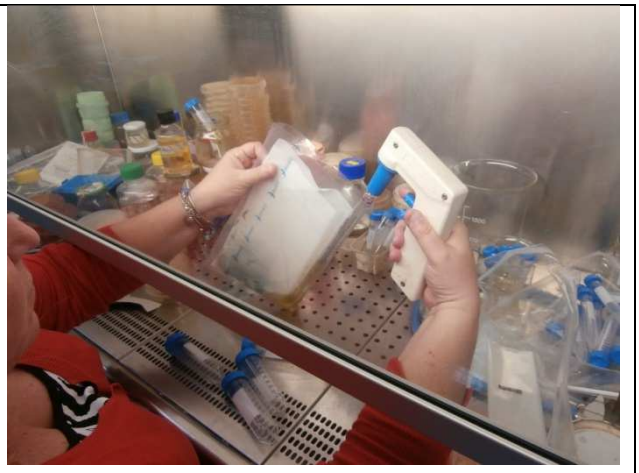
Figure 124: Tools for microbiological analysis

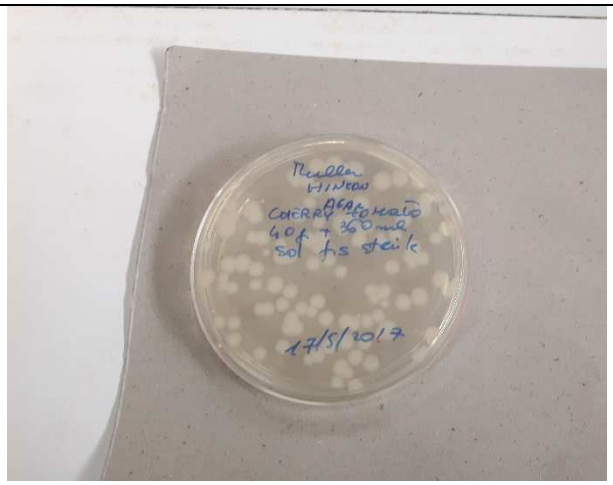
The procedure for sample preparation is quite straightforward. The main aspects to be taken into account is that the crew has to pay attention to not contaminate the samples, therefore he has to wash his hands before starting the operations and wear latex gloves. Another important aspects is that for each microorganism culture three plates have to be prepared to ensure the reliability of the measurement. The procedure is done of several phases (it is described for one single media, for the others the steps are the same):

- **Phase 1: Items preparation**. Crew has to prepare all the items and tools to be used and ensure that they are sterile or have been sterilized (like for example the water to prepare the solution or the pipetters tip.
- **Phase 2: Preparation of the samples**. The sequence is shown for leafy greens. Nevertheless the same sequence applies to the fruit and radish plants.

Step1: Prepare, weigh the selected vegetable (from 10 to 50 g, depending on the vegetable) and wash it with fresh water	
Step. 2: Immerse the vegetable in a solution of water and hypochlorite (2%) for 15 minutes. Then wash with fresh water until the hypochlorite is completely removed	
Step 3: Immerse the vegetable in a solution of water and sodium bicarbonate (50g/l) for 15 minutes. Then wash with fresh water	

Step 4: Put the vegetable in a mortar ad crush it by means of the pestle until it is reduced in a fine paste. Then add distilled water or physiological solution and stir the solution	
Step 5: Put the solution in a filter bag	
Step 6: Prepare and label an Eppendorf Conical Tube	
Step7: Preparation of the pipetter. Open the pipette package and with the pipetter engage the pipette.	

Step 8: Using the pipetter, transfer the liquid part form the filter bag to the Eppendorf conical tube	
Step 9: Using the adjustable volume pipetter, take 100 microliters of the solution form the Eppendorf conical tube	
Step 10: Using the adjustable volume pipetter, inject the solution in the plate (3 plates to be prepared)	

Step 11: Using the spatulas, distribute gently the solution in the plates. Proceed until all the liquid part has been absorbed by the culture media	
Step 12: Put the plates in the incubator for 24 hours	
Step 13: Remove the plates from the incubator and verify the results (in the picture on the right the example of an undesired bacterial contamination)	

8.3.3.b Culture media preparation (optional)

Alternatively the media can be provided as dried powder to be used to prepare agar plates and/or cultivation broth. This ops manual also describes how to use them to prepare the above mentioned plates or vials, should be necessary in the future to do that.

Fig. 125: Culture media (top) Bunsen Burner (bottom – left), pressure cooker (bottom – right)

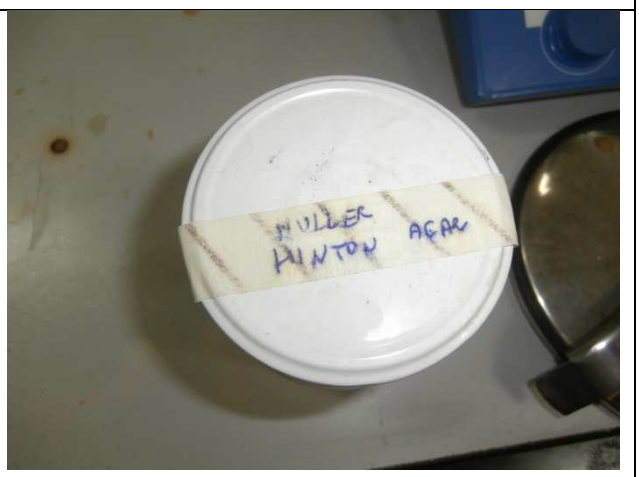
Items needed:

- Glass Jar with cover lid
- Autoclave tape
- Pressure Cooker: in the absence of the autoclave, the use of pressure cooker is necessary to sterilize little volumes of media, as well as tips or physiological solution. Of course, there is a difference with the conventional autoclave, due mainly to the different conditions (in terms of temperature and pressure). In principle the use of a pressure cooker will require an higher temperature (at least 270°C instead of 121°C that is the conventional T used for the autoclave), and a longer heat treatment time (at least 30 minutes, instead of 15 minutes). The autoclave tape will be used to assess the successfully sterilization of the solution.
- Heating stirring plate: it is needed to provide the heat to the pressure cooker and to stir the solution.
- Bunsen burner. The preparation of the samples for safety analysis should be done in a laminar flow hood, but that is not possible since NMIII is not equipped with it. The Bunsen Burner can overcome this problem and can provide a simple way to improve the sterile conditions as requested. In fact the contamination during the handling of the bottles or flasks containing the media or physiological solution and previously sterilized in the pressure cooker, can be minimized working close the flame of the Bunsen burner, or even better moving the top of them in the proximity of the flame itself. It is worth to underline that Bunsen burner has been widely used in microbiology before the diffusion of more modern equipment like the above mentioned lamina flow hood.

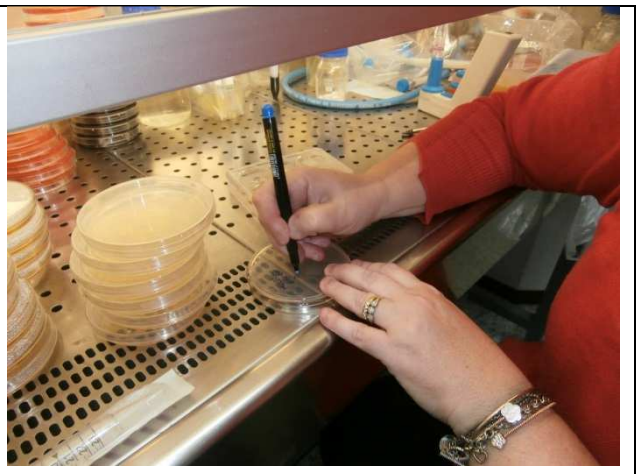
Finally deionized and sterile water has to made available for the preparation of the preparation of culture media.

- **Phase 1: Culture media preparation**. This phase is done of several steps as described in the following:

Step 1: Take the selected growth media (the weight is depending on the number of sample to be prepared) and put it in a transparent glass jar. Add Agar in proportion 1.2 – 1.6%. Then add distilled water as necessary	
Step 2: Put the jar on the heating/stirring plate and activate the stirrer for a couple of minutes (Alternatively a spoon can be used)	
Step 3: Close the Jar with its lid cover and put on the lid the autoclave tape. Write on the Autoclave tape the type of culture media under preparation.	

Step 4: Put the jar in the pressure cooker and close the cooker lid. Be sure that some water is in the cooker. Put the cooker on the heating/stirring plate and activate the heater at 270 degC for 30 minutes	
Step 5: After 30 minutes open the pressure cooker (wait for the complete depressurization of the cooker - visible with the complete decrease of water vapour) and verify that the color of the transverse lines on the autoclave tape have turned to brown (ig these transverse lines are still white, repeat the operation).	
Step 6: The solution is ready for use. It is suggested to move the autoclave tape from the cover to the jar side or to add a new label.	

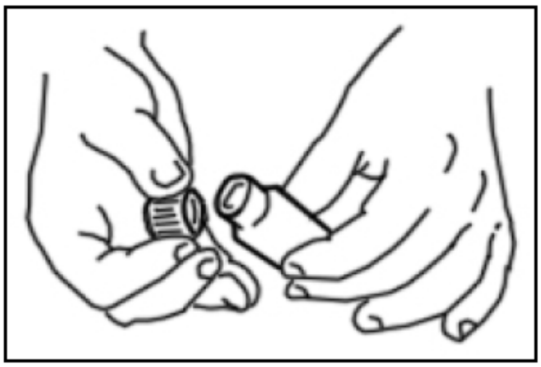
- **<u>Phase 3: Plates preparation</u>**. This phase is aimed at the preparation of the supports for microorganism culture. It is important to underline that this phase require several hours to have the growing media inside the plates completely solidified. For that reason it can be done the day before the preparation of the samples. Remark: In this document, the images show the procedure as executed using a laminar flow hood. The usage of the Bunsen Burner will be documented in the procedure to be developed.

Step 1: Plates labelling. That has to be done on the bottom of the plates to avoid mistakes when the covers are removed (could be reinstalled on the wrong plate)	
Step2: Preparation of the pipetter. Open the pipette package and with the pipetter engage the pipette.	
Step 3: Suck a 20 ml of solution	

Step 4: Inject the solution in the plate. Avoid the creation of air bubbles, and if that happens just suck back them. Repeat for additional two plates (three in total).	
Step 5: Wait until the solution solidify leaving the cover open, as shown in picture.	

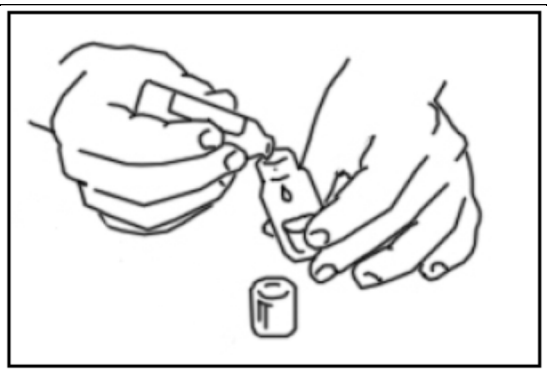
8.3.3.c Vial operations

The kit comes in a pack containing all the material for the analysis: the reaction vial (vial) and a vial of distilled water (vial of water). To perform the analysis a bacteriology thermostatic incubator programmable to 30°, 37° or 44°C is needed. The performance analysis can be summarized into 5 phases: opening, insertion of the sample, early analysis, order analysis and sterilization. Before handling the vials and proceeding with the analysis a thorough hand washing is recommended.

Step1: Vial Opening Open the vial, taking care to flip the cap so that the inner surface does not come into contact with the surface to avoid contamination	

Step2: Start analysis

Open the vial of water supplied with the reaction vial, and insert the entire contents of the vial itself.
Mix by shake the vial until the reagent is completely dissolved and no solid powder is present (20 seconds using a vortex).

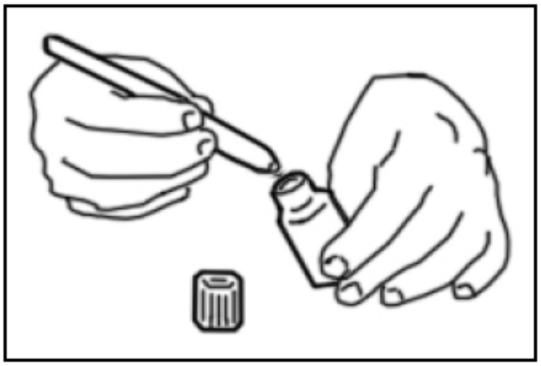


Step 3: Inserting the sample

Take a small aliquot of the food (about the volume of a grain of corn, approximately corresponding to 1 g) with a tool used during the processing of the food itself and insert it into the vial (alternatively you can use sterile tweezers).
Accurately mix the sample with the solution contained into the vial by inverting the vial several times.
Place the vial in the incubator thermostat and set the temperature as per reagent requirement

Note:

1. the size or the exact weight of the sample to be examined is not so important. however, the sample must be reduced to a very small parts (maximum size 2-3 mm)
2. for inserting the sample into the vial, we recommend using a tool used during the processing of the sample itself, since by so doing, you will be able to detect any contamination of the sample due to extrinsic causes



NOTE

THE INCUBATOR TEMPERATURE AND THE INCUBATION DURATION ARE DEFINED AS FOLLOW:

REAGENT	U.M	Limit of Acceptability	TEMP. (degC)	TIME OF OBSERVATION (hh.min)
TOTAL VIABLE COUNT	CFG/g	10^7	30	03:00
COLIFORMS	CFU/g	10^3	37	16:35
ESCHERICHIA COLI	CFU/g	10^3	44	26:00
SALMONELLA SPP	CFU/g	0	37	67:00
LISTERIA SPP	CFU/25g	0	37	36:00

ANY CHANGE IN THE COLOUR OF THE SOLUTION BEFORE THIS TIME REPRESENT A LEVEL OF CONTAMINATION HIGHER THAN THE ACCEPTABLE LIMITS. SHORTER IS THE TIME, HIGHER IS THE LEVEL OF CONTAMINATION.

Step 4: Check of the analysis result

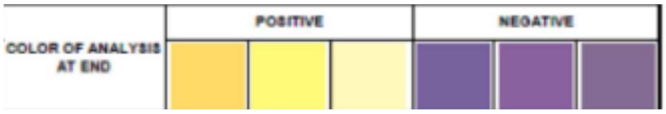
Check periodically for color status. Log on the log journal the time and the results of the observation. Report to MCC at the end.

Note:

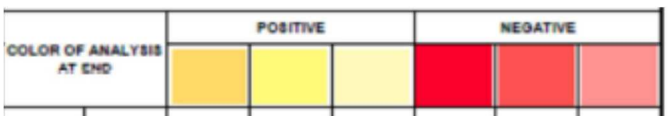
1. for long time of observation it is recommended to have intermediate check's.
2. the analysis result is positive if, and only if, occurs a complete color change of the vial content
3. the color palette, as well other relevent informations are provided in the detailed procedure.

COLOR PALETTE

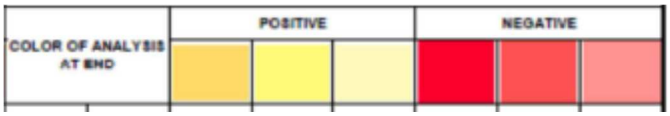
Total Viable

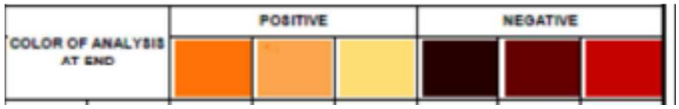
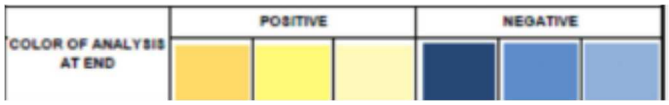
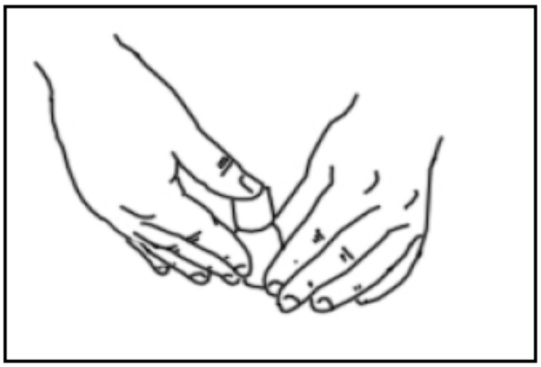


Coliform Control



Escherechia Coli



	Salmonella  **Listeria** 
Step 5: Post Analysis Sterilization After analysis, without opening the vial, firmly press the top of the cap and shake for about 10 seconds. After 5-10 minutes the contents of the vial is completely sterilized. **Note:** 1. sterilization of the vials is required before the disposal **2.** the addition of the sterilizing agent can cause a further color change	

8.3.4 Post mission Safety Analysis – Sample collection

As far as the post mission analysis is concerned, samples will be collected and stored and sent to the European Lab's . The collection has to be done avoiding as much as possible contamination, therefore the operator is required to use sterile gloves and sterilized scissors or slicers.

For each type of vegetable, the sample number is identical to that used for quality evaluation. About 10 grams/sample will be stored in sterile tubes of 50 ml volume and or sterile plastic bags. Both tubes and/or sterile plastic bags will be kept in a freezer, at -20°C/-30°C. To avoid microorganism death samples cannot be freeze dried. The frozen samples will therefore be stored in the presence of sterile glycerol. Samples should be mixed with one fifth (respect to weight) of sterile glycerol, then kept in freezer.

8.4Microbial Analysis

In addition to the safety analysis done by CNR and LIT, a microbial analysis will be also by DLR using a different methodology. This analysis will be conducted not only on the plants but also on the MTF surface, to understand if and how there is a microbial proliferation that is affecting the entire MTF environment and that could be critical for the operator. Two different methodologies are envisaged for the EDEN ISS operations, the first is related to a sampling activities aimed at the collection of samples (of both surface contaminant and plant parts) for off line analysis, the second to be conducted on site by means of the so called E-Nose instrument.

8.4.1 Sampling for off line analysis

The procedure for sample collection is a very easy task, but as seen for the food safety analysis the most important and critical aspect of it is that the crewmember has to avoid sample contamination. That can be achieved by carefully washing the hand and wearing sterile nitrile gloves before the operations start. Different samples have to be collected for microbial and molecular analysis.

Several tools are required for the operations as listed in the following table10 and shown in figure 126

Table 10: Tools and Items List

Tool	Surface Sampling	Plant sampling
Laboratory Journal	x	x
Markers	x	x
Sterile Nitrile Gloves	x	x
Nylon Flocked Swab (+ container)	x	
„Eppendorf“ tube (2 ml)	x	
Centrifuge tube (15 ml)	x	
Tweezers		x
Scalpels		x
Centrifuge tube (50 ml)		x

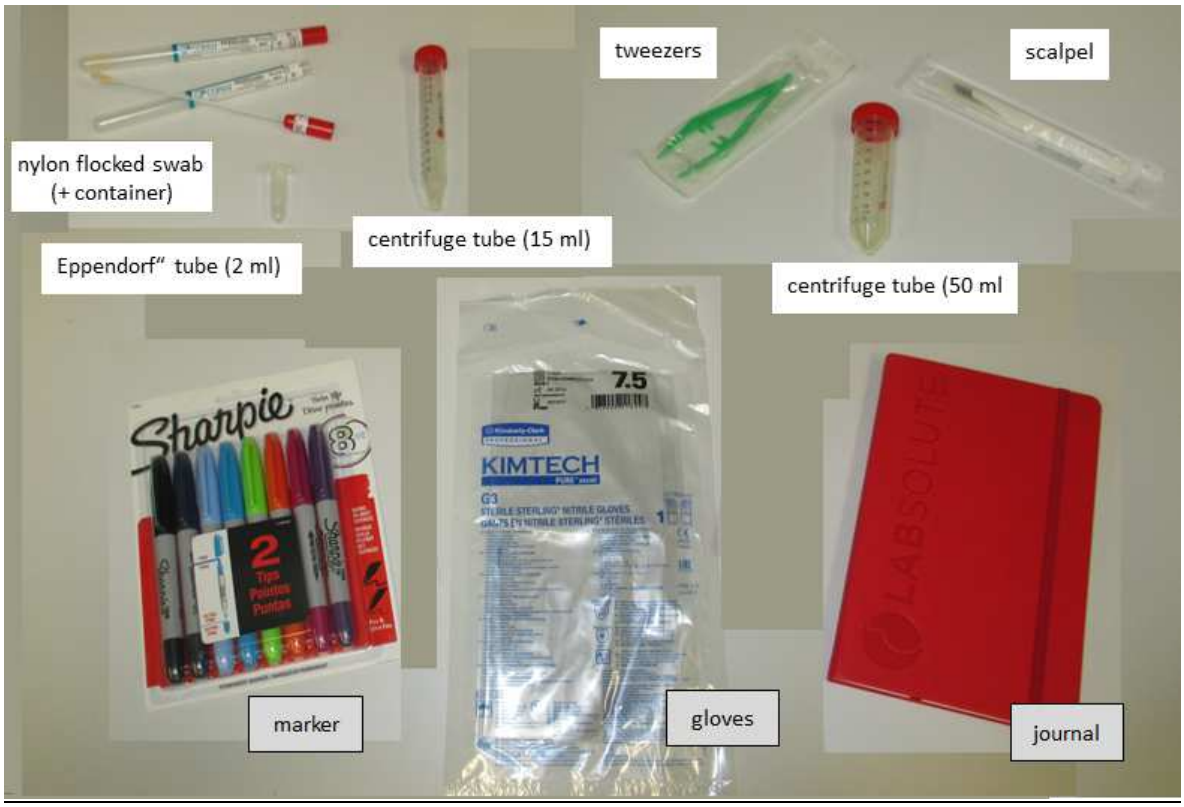


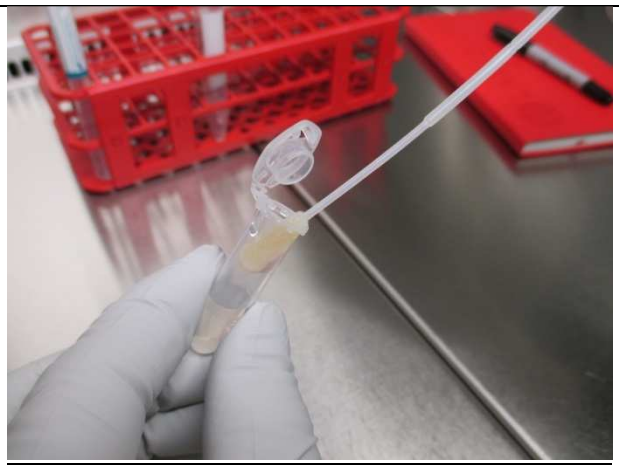
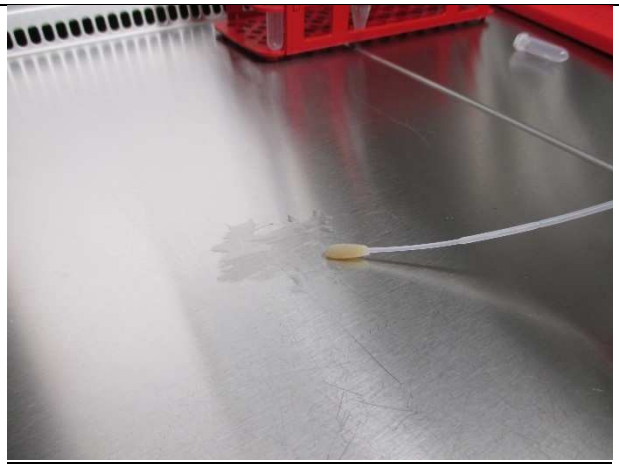
Figure 126: Tools for microbial sampling

For both the surface and plants sampling activities, the procedure is done mainly of the following three macrosteps: (Remark: all the detailed steps will be inserted in the related procedures):

1. Prepare the tools

2. Take samples (+ 2 field negative control)
3. Store the samples @ -18degC

Surface Sampling (different samples, but same operations for microbial and molecular analysis)

Step 1: Prepare the swab o Remove the swab from its container o moisten the head of the swab using the sterile water in the sterile Eppendorf tube	
Step 2: Swab the surface o Swab the surface, rotating the head of the swab slowly and thoroughly over a measured 25 cm^2 surface area. Repeat from three different directions.	
Step 3: Store the swab o Put the swab in a sterile centrifuge tube (15 ml) containing 2,5 ml sterile water o Label and store @-18degC the sterile centrifuge tube	

Plant sampling (different samples, but same operations for the microbial and molecular analysis)

Step1: Prepare the tools o Remove the scalpel and the tweezers from their pouches	
Step 2: Collect the sample o Grab a leaf (or another plant part) with tweezers and cut it with the scalpel	
Step 3: Store the sample o Put the plant part into a centrifuge tubes (50 ml) o Label the centrifuge tube and store at -18 degC	

The following table 11 gives an estimation of the microbial investigation sample return requirements of the Antarctic deployment phase.

Table 11: Sample to be returned

Element / Component	Qty	Mass per element (kg)	Total mass (kg)	Notes
15 mL centrifuge tube + 2.5 mL water/PBS + swabhead	250	0.0095	2.375	Analysis by cultivation
FLOQSwab	250	0.006	1.500	Analysis by molecular techniques
50 mL centrifuge tube + wipe	30	0.05	1.500	Tubes for wipes
50 mL centrifuge tube + plant parts	270	0.04	10.800	Tubes for plant parts
50 mL centrifuge tube + snow	30	0.05	1.500	Tubes for environmental samples (e.g. snow)
		Subtotal (kg)	17.675	
		Margin (%)	10	
		Grand total (kg)	19.4425	

8.4.2 E-Nose Operations

An alternative method to the sampling will be also exploited during the MTF operations in Antarctica. For the Bio-Detection of the biological load on several surfaces but also on the plants the commercial E-Nose PEN3 of the company AIRSENSE (see Figure 127) will be used within the greenhouse. This portable device is based on MOS-Technology (metal oxide semiconductors). An electronic nose possesses an array of chemical sensors, which are sensitive on gas molecules. This sensor array is in connection with a data acquisition unit.

Surfaces or samples can be analyzed by this device and existing fungi and bacteria can be located. This device is optimized to analyze the VOC`s (Volatile Organic Compounds) which are produced by the bacteria od fungi.

Figure 127: E-Nose

This device has internal pumps for taking samples. Sample gas is sucked in by a sample taking unit and is analyzed by the sensor array of 10 metal oxide semiconductors. The status of the device is traced by the display on the front side. All generated data is stored onto an internal data storage and can be transferred to an external PC. For the data transfer and the data evaluation the commercial software WinMuster will be used. Between a sampling and another one, a purging activity is possible with the objective to clean the sensors from previous contamination. A schematic diagram is presented in fig. 128

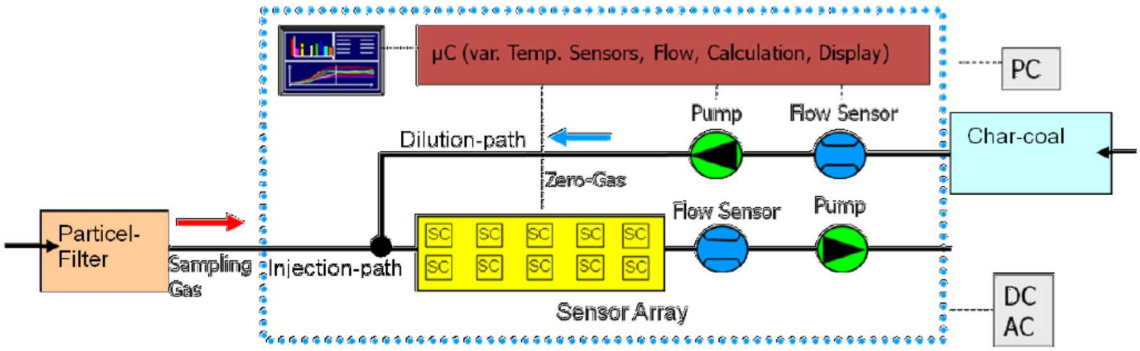


Figure 128: E-Nose Schematic Diagram

While the sampling of the MTF surface is quite straightforward, the sampling of the plants is a little bit tricky since the plants do not have flat surface. Two different methods will be used, both of them foresees the utilization of the so-called air sampler (fig. 129)

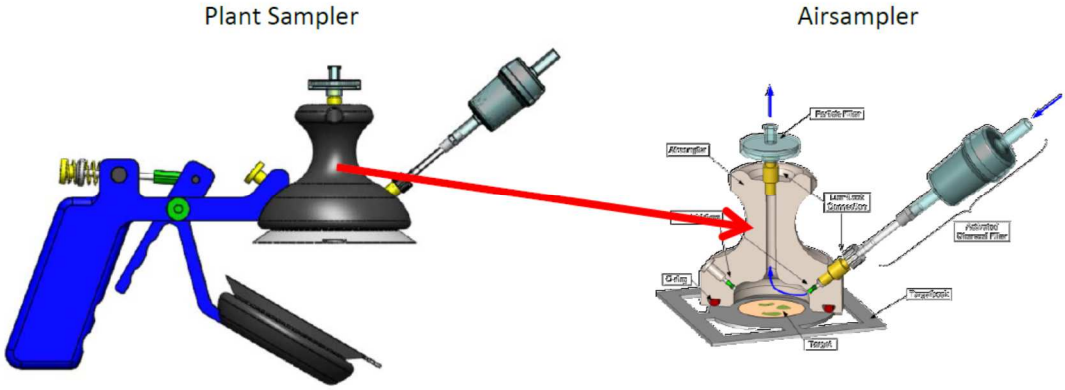


Figure 129: Air Sampler

Figure 130: Direct measurement on leaves

Figure 131: Contact plate

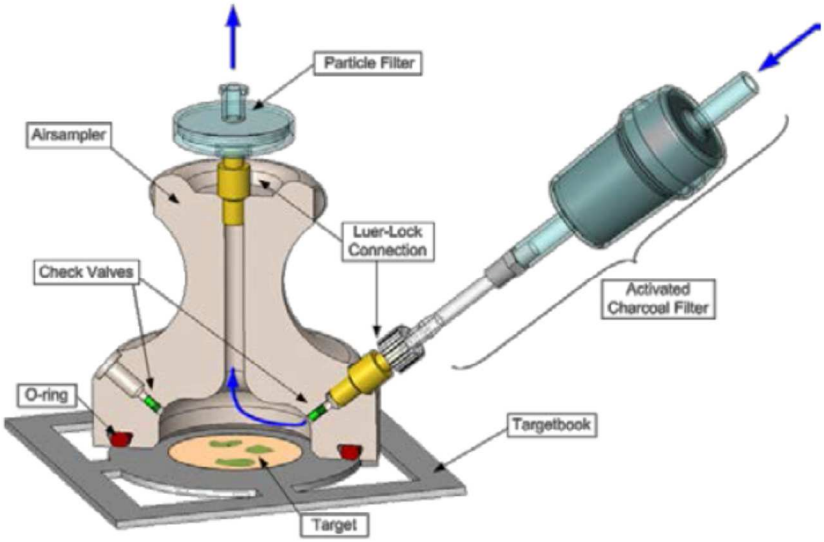


Figure 132: microbial analysis on contact plate

In the first case the air sampler will be mounted on a support to take measurement directly on the leaves (fig. 130), in the second case the measurement is done in two steps:

1. acquisition of the microbes/fungi by means of a contact plate (Fig. 131),
2. the analysis of the contact plate by means of the Air sampling (fig.132). The Contact Plate has to be placed in the Target position, and the E-nose sensor inserted in the particle filter hole).

Both methods don't perform well for all the cases, therefore it has to be decided (with the support of the remote experts) what is the methodology to be used. For example, the first method does not work with the plant trunck. For the second methods it has to be considered that the contact plate is able to acquire on its surface only the 5% of the contaminants.

8.5 Decontamination

If "dangerous" contamination is found with the microbial investigations mentioned above, a decontamination activity could be necessary, Should be this the case a portable system is available at the Antarctic site for the decontamination operations. This system generates a very fine mist (2-5 µm) of Vaporized Hydrogen Peroxide (VHP). It eliminates bacteria and fungi, which can be the most hazardous contaminations within the FEG.

Figure 133: Decontamination system

The maximum volume, which can be disinfected, is accounted for 270 m_3. The decontamination system can be used in two different ways:

Decontamination System inside the greenhouse

The decontamination system can be deployed inside the greenhouse. The system stays compact at one place.

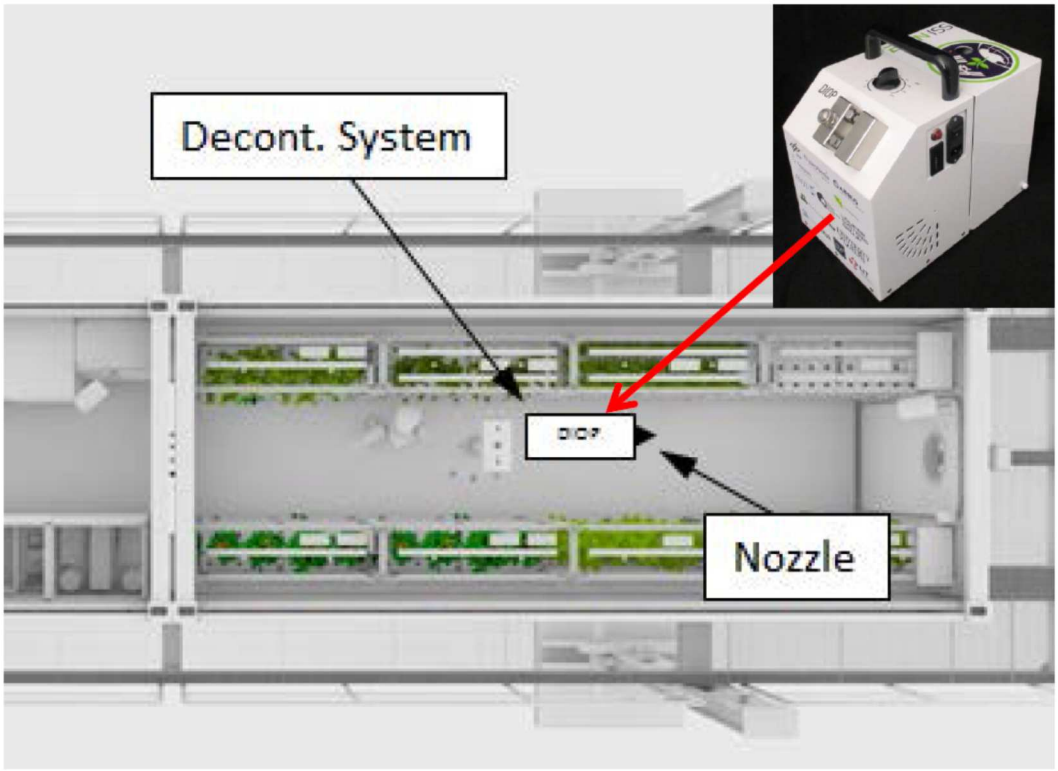


Figure 134: System placed inside the FEG

Decontamination System outside the greenhouse, nozzle inside

The decontamination system can be split up into two pieces (Fig. 135 and Fig. 136)

Figure 135: Decontamination system, split in two parts

In this case the compressor can be placed outside the FEG and can be operated from there (service section). The nozzle is deployed inside the greenhouse and sprays the agent. After completion of the de-contamination process, the system shut down automatically.

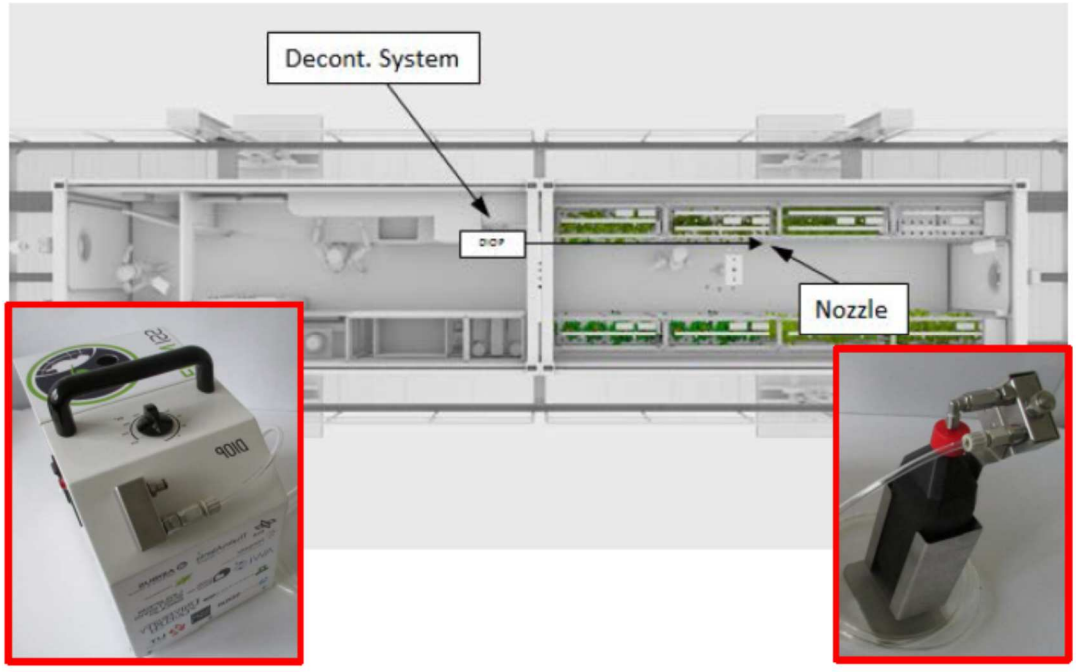


Figure 136: Two items decontamination system deployed

In both the cases It has to be considered that during the decontamination the user has to leave the FEG and that the entrance of other person (even by mistake) shall be avoided. As matter of fact the entrance in the FEG is permitted not before than 90 minutes from the end of the disinfection process.

8.6 ISPR Rack Operations

Similarly to the FEG operations the routinary tack operations falls in two categories:

- Nominal Operations (those aimed at the preparation of the rack for plant growth cycle)
- Science operations (those aimed at the control of the plant growth cycle and the verification of Plants Health and Status and at the collection of samples for off line quality and safety analysis). This chapter deals with their description

8.6.1 Nominal Operations

Two different kind of nominal operations have to be considered. The first is aimed at the preparation of the root modules, including the seedling part, the insertion in the Growth Modules and the connection to the Nutrient Delivery system. The second is aimed at the configuration of the ISPR Rack in terms of definition and control of the environmental parameters for plant growth (Light Intensity and Composition, Temperature, Humidity Level etc.).

Several prerequisites have to be satisfied before starting the operations as listed below:

1. All the ISPR subsystem have been installed and are ready for operations
2. All the connections (cables, hoses, etc) have been done
3. The NDS water tanks has been filled with water and the soft bags have been filled with concentrated stock solution A and B and with acid solution
4. ISPR Configurations Files have been prepared in advance

Part of these activities have been completed during the commissioning phase. On the other hand, the NDS tanks refilling is considered as planned maintenance and periodically scheduled, while it is assumed that the ISPR Configuration file preparation have been prepared and validated during the AIT phase and ready to be used.

PREPARATION OF THE ROOT MODULE

This operation is done of several steps as follow:

1. Seeding (Pillows preparation)

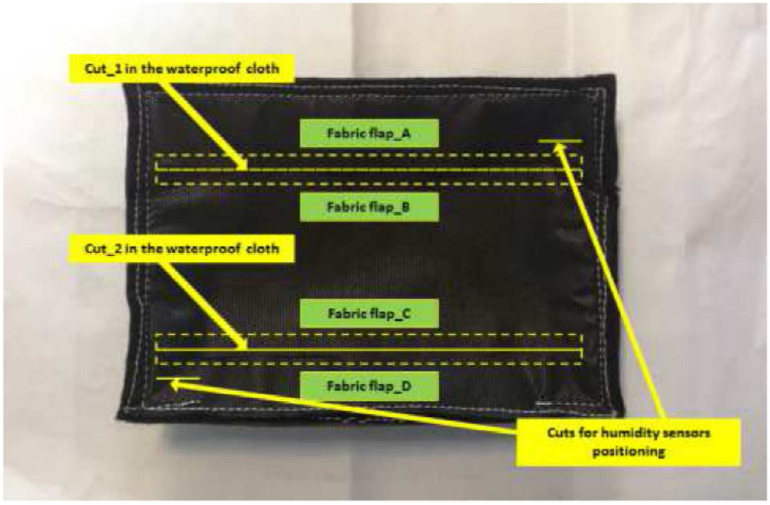


Figure 137: Substrate Pillow

1.1. Prepare 2 paper strips of about 3 cm x 20 cm
1.2. Distribute some seeds on paper strips using Agar (the number of seeds is plant depending)
1.3. Cover the first paper strips with a second strip having the same dimensions.

1.4. Lift the fabric flap 1 (see Fig. 137) and place the paper strip between porous fabric and the water-proof one
1.5. Prepare other 2 paper strips of about 3 cm x 20 cm
1.6. Paste the required seeds using Agar.
1.7. Cover the first paper strips with a second strip having the same dimensions.
1.8. Lift the fabric flap 2 and place the paper strip between porous fabric and the waterproof one

The step 1 has to be repeated for each of the four needed sealed pillows.

2. Opening the Growth Chambers

Remark: the procedure is the same for Tall and Short Growth Chambers, hereinafter named respectively GCT and GCS

2.1. Check the Rack is off
2.2. Disconnect the connectors from the GCT / GCS front panel.
2.3. Disconnect manually power and Data connectors located on GCT / GCS bottom panel.
2.4. Disconnect fluidic fittings located on the inlet water line.
2.5. Disconnect all electrical connections and TCs from the THC of both GCT / GCS
2.6. Pull GCT / GCS drawer out of EDEN ISS Rack until the stop.
2.7. Make sure that rear connectors are actually disconnected.
2.8. Unscrew the screws that secures Plexiglas panels to the GCT / GCS lateral side.
2.9. Remove Plexiglas panels from GCT / GCS.

3. Pillow installation in the Root Module

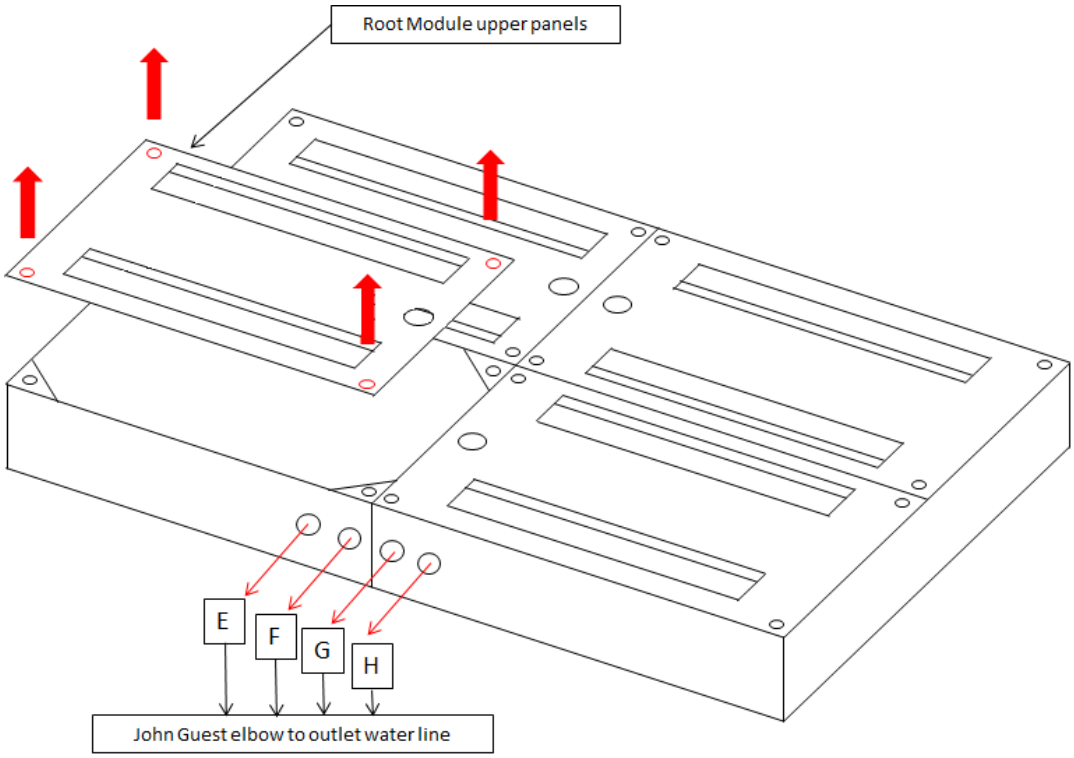


Figure 138: Root Module – Top Panel

3.1. Remove the Root Module Upper Panel (x4)

3.2. Deinstall the Porous Plates (x4)
3.3. Insert the pillows in the Root Module (x4)
3.4. Re-install the Porous Plates
3.5. Re-Install the Root Module Upper Panels

4. **Installation of the Root module inside the GCT/GCS**
   4.1. Prepare 8 velcro strips with the same size of the removed ones so that, 4 strips are formed by the layer covered with tiny loops and 4 strips are formed by the layer with tiny flexible hooks. Don't remove the protective film that protects the glue.
   4.2. Divide into couples the strips so that each couple is formed by one layer covered with tiny loops and one layer with tiny flexible hooks. Don't remove the protective film that protects the glue
   4.3. Press together the two layers of each couple.
   4.4. Remove the protective film that protects the glue only on one side of each strips couple.
   4.5. Attach each strips couple on the Root Module lower side
   4.6. Tilt Root Module of about 45° to the vertical.
   4.7. Relocate Root module inside the GCT. Pay close attention to GCT instrumentation while installing Root Module inside GCT
   4.8. Tilt Root Module again so that it is parallel to the GCT lower side (ground)
   4.9. Make sure that Root module is centered inside the GCT.
   4.10. Pull Root Module down slowly so that Velcro strips could join firmly together

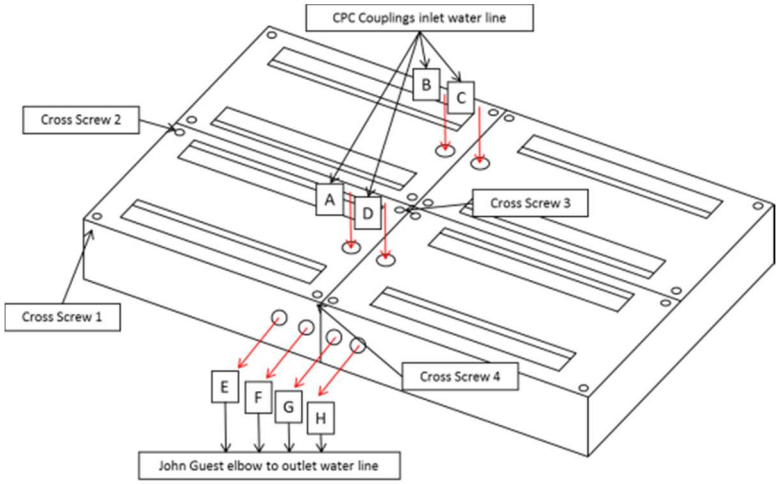


Figure 139: Fluidic Connectors

   4.11. Connect the inlet water line QDs: A, B, C, D (see Figure)
   4.12. Connect the outlet water line QDs: E, F, G, H (see Figure)
   4.13. Install the soil moisture sensors

5. **Closing the Growth Chamber**
   5.1. Install the Plexiglas panels from GCT / GCS. Tighten the screw
   5.2. Pull until stop the GCT / GCS drawer inside the ISPR Rack
   5.3. Connect all electrical connections and TCs from the THC of both GCT / GCS
   5.4. Connect fluidic fittings located on the inlet water line
   5.5. Connect power and Data connectors located on GCT / GCS bottom panel
   5.6. Connect the connectors located on GCT / GCS front panel
   5.7. Switch ON the Rack.

ISPR RACK ACTIVATION AND CONFIGURATION

These operations are composed of the following steps:

1. Laptop connection to the ISPR PCDH
2. Laptop Activation
3. Program RUCOLA Load (Fig. 140)

Figure 140: Program RUCOLA load page

4. At the end of the loading phase the RUCOLA SW Main Page (Fig. 141) will appears on the screen. At this time, since the rack is still Off, this display will show only dummy parameters

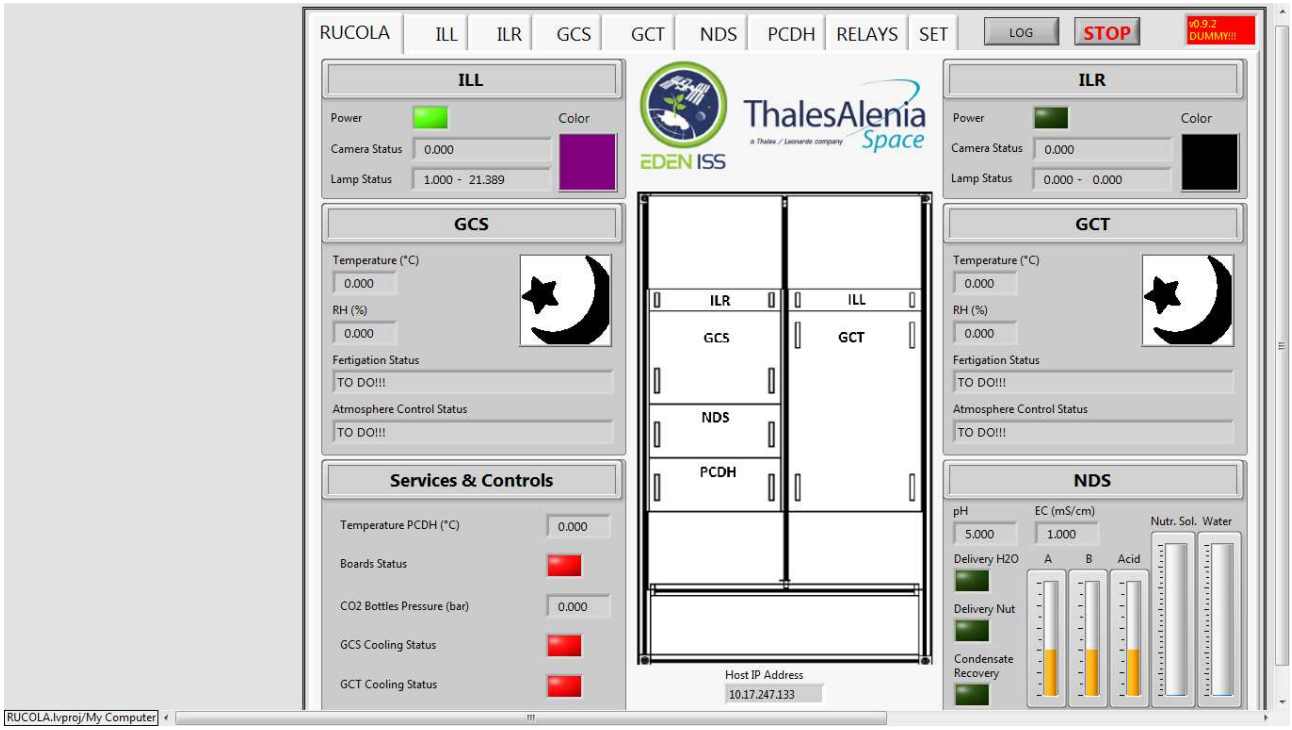


Figure 141: RUCOLA SW Home Page

5. On the S/S Power Panel Switch On the ISPR Rack switches
6. On the lower panel of the ISPR Rack Switch On the power switch
7. On the ISPR Screen check TBD
8. On the RUCOLA SW Home Page/Services &Control, verify the Board Status is Green
9. Navigate to the Initial Configuration Display (fig. 142)

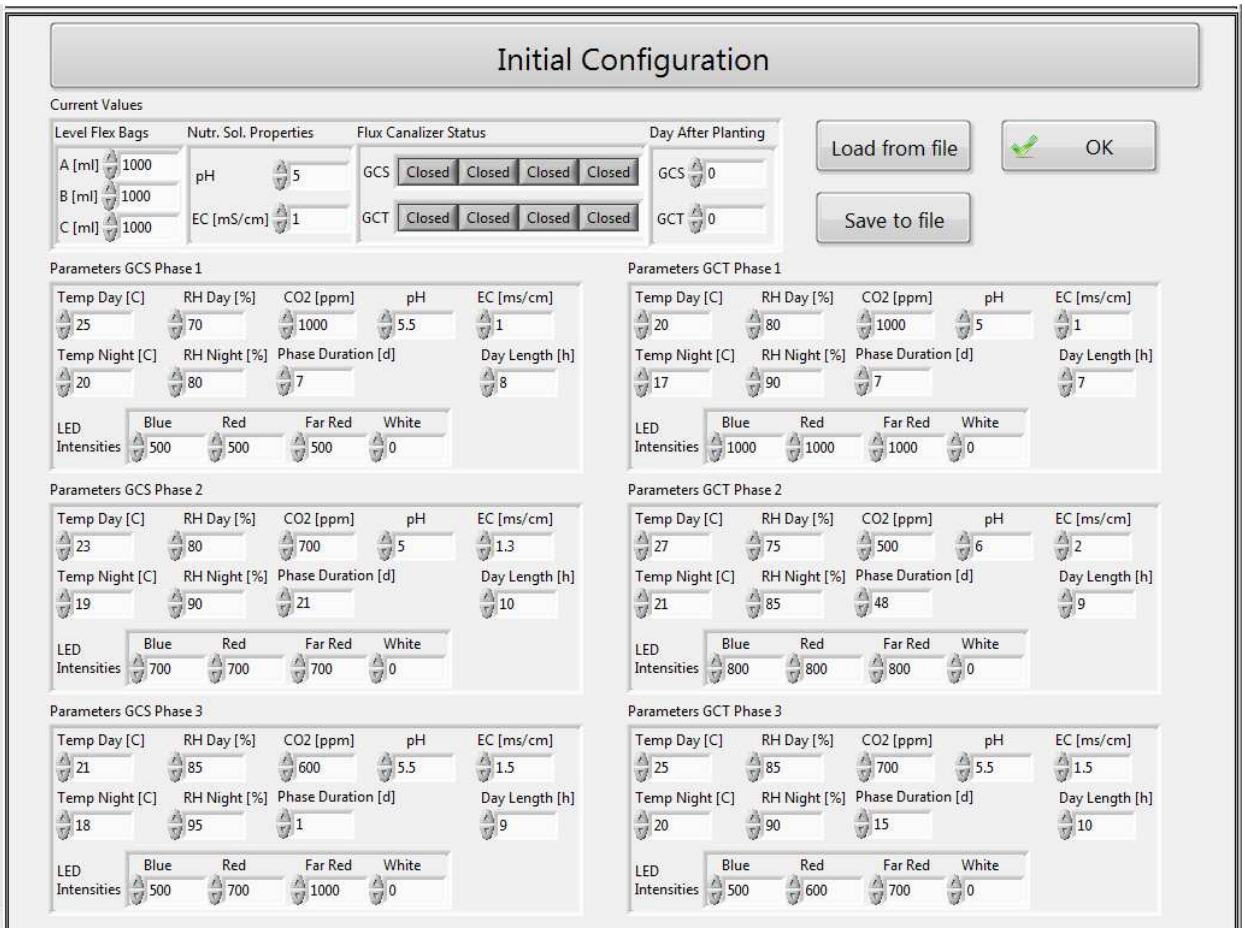


Figure 142: Initial Configuration Display

10. Load the needed configuration file. Click on **Load from file** button, navigate to the file folder, select the right one
11. On the Initial Configuration Display verify that the loaded parameters are the right one (TBC)
12. Periodically check the telemetries on the Growth Chambers Control display (fig. 143)

Other displays are available for further control. They can be used as necessary.

Figure 144: Growth Camber Control Display

8.6.2 ISPR Science Operations

Several operations falls in this category aimed at both the control of the plant growth cycle, and the collection of sample for off line analysis, and it is quite clear that for the most part of them there are no differences with respect the same activities done for the FEG, with two main differences:

1. All the activities requiring interaction with the plants (like pruning, training, harvesting, etc) and the collection of plant samples require the access to the inner part of the Growth Chambers. Therefore they have to preceded by an activity for Growth Chamber extraction and followed by an activity for Growth Chamber re-installation.
2. Air and water sampling require their own procedure.

Being the procedures related to the first bullet the same already described for the FEG, this chapter deals with the **only** description of the procedure related to the activity for water and air samples collection for off line analysis.

ISPR NUTRIENT SOLUTION SAMPLE COLLECTION

This activity is done of the following steps:

1. Stop Rucola software “Operation Mode”
2. Move to sampling Mode
3. Connect a female QD on sampling port the male fitting (see Fig.145)

Figure 145: NDS Sampling port

4. Press “Start to sample” button. Software automatically runs the pump in such a way that the required amount of nutrient solution is delivered from the system to a sampling bag / bottle.
5. When the required amount of nutrient solution is delivered from sampling port, stop the pump
6. Remove sampling bottle by disconnecting male to female fittings
7. Set Rucola in Normal Mode
8. Analyze the nutrient solution and collect data.

ISPR AIR SAMPLE COLLECTION

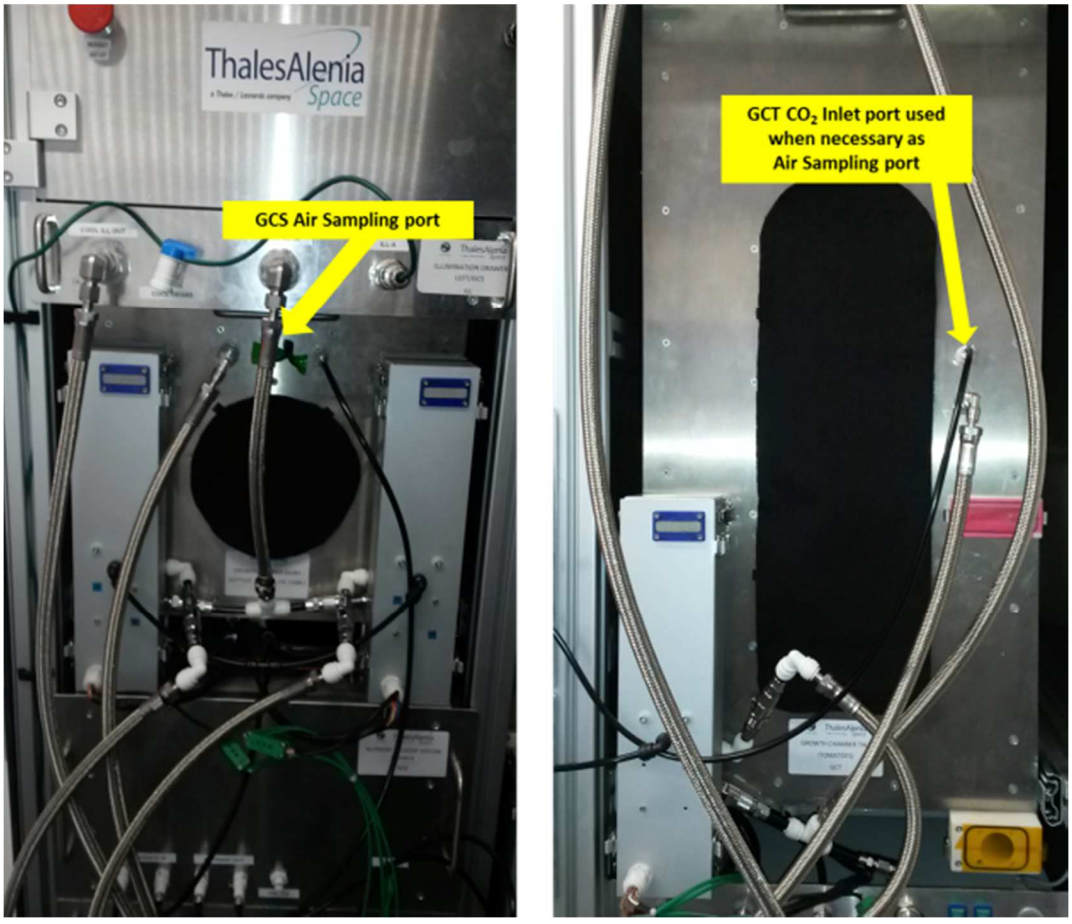


Figure146: Growth Chambers Air Sampling Ports

1. Set Rucola software to “Sampling Mode”
2. Move to sampling Mode
3. To get an air sample from the GCS, connect a female QD in the position showed in Fig. 146, left side
4. To get an air sample from the GCT, detach CO2 inlet fluidic fitting from GCT front panel and, after that, connect an half QD (see Fig. 146 - right side)
5. Press “Air Sampling Start” button. Software automatically runs the THC fun in such a way that the required amount of air is delivered from the system to a sampling bag / bottle and replaced with the same amount of external air.
6. When the required amount of GCS/GCT air is delivered through sampling port, press “Air Sampling Stop” button
7. Remove air sampling bag.
8. IF a GCS internal air was sampled, move to step 10
9. If a GCT internal air was sampled, reconnect CO2 inlet port and, after thatr, move to step 10
10. Set Rucola in Normal Mode
11. Analyze the sampled and collect data

8.7Maintenance

Several maintenance activities are foreseen during the EDEN ISS lifecycle, ranging from nominal cleaning of the exterior and of the interior of the MTF to more complex system maintenance activities. This chapter deals with their description, with a focus on those considered most important.

8.7.1 Solid Waste Management

The solid waste generated with the MTF and the EDEN ISS associated activities conducted within the NM-III multipurpose laboratory will be composed of inedible biomass, consumables such as cleaning wipes, lab hygiene equipment (e.g., disposable gloves, overshoes, lab coats), packaging (e.g., seeds, consumable related packaging, nutrient salt containers) and failed components. Solid waste components will be dealt with through the existing NM-III waste handling systems/protocols including sorting, stabilization/storage, labelling, reporting and subsequent shipment off the Antarctic continent. Harvested plants will be separated into edible biomass and inedible biomass before leaving the MTF. Edible biomass will be stored into an insulated cooler containing enough ‘thermal inertia’ to ensure that the material does not freeze (in particular remains at ‘room temperature’) during the outside transfer between the MTF and NM-III (even in the middle of winter). Inedible biomass will be transferred into more nominal storage containers and transferred into the station. In all cases, material will be stored in tightly sealed boxes before being removed from the MTF for transport to the station. Upon arrival into NM-III waste biomass will be handled similarly to kitchen food waste. Once appropriately packaged it will be placed in the cold part of the station/garage in waste containers where the low/freezing temperatures will prevent the generation of odors. All efforts will be made to avoid and minimize packaging and unrequired shipping supplies required for the transfer of the greenhouse module, equipment and supplies from Europe to the Antarctic.

Figure 147: (Left) NM-III long-term waste storage (waste sent out of Antarctica on Polarstern). (Right) NM-III waste separation streams.

8.7.2 AMS Maintenance

Three main maintenance activities of the Air Management System are nominally necessary as part of the EDEN ISS operations:

- Filters Replacement
- CO2 Bottle replacement
- Thermal Cooling lines refill

As far as the **filter replacement** is concerned, three filters are installed in the AMS unit: a prefilter, an absolute HEPA filter and a VOC (Ethylene) filter. Prefilter and absolute filter are controllable by a pressure differential transmitter because they change the pressure drop when clogged: this transmitter will send a signal to the remote panel and when the alarm level is reached the filters have to be replaced. This operation is easy, by a frontal panel with 4 latch, manually screwed without tools. For the VOC filter, chemical type, the pressure drop doesn't change: the only possible control is the colour change of the filter media, visible through a sight seen directly put on the filter case, so in local. The procedure to change this filter is the same of the previous filters. Anyway the filters are designed for a duration of prefilter 3 months, absolute filter 6 months and VOC scrubber > 1 year: after those periods is suggested to change the filters, also without a clogged filter alarm or a change colour of filter media.

CO_2 level in the storage cylinders has to be periodically checked. The CO2 storage cylinders have to be replaced as soon as the CO2 level falls below a defined threshold.

8.7.3 NDS maintenance

Fresh water tank filling

Fresh water tanks filling is necessary when the water level goes below a defined threshold. When that happens a low water level alarm is set from Argus requiring the operator to fill the tank. A periodic check of the tank level could be considered to avoid system stops for water refill.
Water for use in NM-III is produced from melting snow. Freshwater taken to the MTF and subsequently the made up bulk nutrient solution will be made up with a small reverse osmosis (RO) system, installed within the NM-III multipurpose laboratory.
Freshwater from the RO system will be filled into tanks and will either be hand carried outside or more than likely, on a cart that can be wheeled down the hallway, into the station elevator and taken to ground level where they will be transferred to a sled and pulled to the MTF. Upon arrival either the smaller tanks will be hand carried up the elevated platform stairs and entered into the cold porch or the operator will connect a tube from the MTF cold porch fresh water refill wall mounted connection to the sled pump and water will be pumped directly into the fresh water tank in the cold porch.

Waste water tank emptying

From a similar perspective, wastewater emptying is necessary when the water level in the tanks goes above a defined threshold. When that happen, tank wastewater has to be removed from the tanks. As above an operator period check could be considered to avoid system stop for waste water removal. By the way, whenever needed the waste water will be pumped into hand carried tanks or pumped directly into a reservoir located on a sled which will be pulled back to NM-III. Upon arrival the tank will be transferred to the NM-III elevator and up to deck 1 and subsequently wheeled down the hallway the NM-III sewage treatment plant. The location of the sewage treatment plant on deck 1 of NM-III as well as a view of the plant from the NM-III corridor are shown in Figure 148.

Figure 148: (Left) Location of the NM-III sewage treatment plant (green colour indicates hallways). (Right) view of the sewage treatment plant from the hallway, illustrating entry door and panels to the sewage plant filter chambers.

The NM-III sewage treatment plant is capable of treating both black and grey water. It is composed of a biological treatment and ultrafiltration (in addition to ultraviolet disinfection), with both parts being combined into one 20 foot standard container. It has been confirmed that the unit can suitably process the expected worst case outputs from the MTF (waste nutrient solution, cleaning water, etc.).

The RO discharge water will be used for other EDEN ISS 'non-critical'/scientific purposes within the multipurpose laboratory (e.g., cleaning) due to its quality being only slightly less pure than the source water entering the unit)

Stock Nutrient/Acid/Base Tanks filling

When the nutrients and/or the acid/base solutions in the Stock nutrient/acid/base tanks (Fig. 149) goes below a predefined level they have to be provided in order to maintain the functionalities of the Nutrient Delivery system. Since these thanks are not equipped with level sensors, a periodic visual inspection has to be considered to verify if the refilling operations is required. In principle, this last does not pose any trouble, since it is just matter to remove the cap and refill the tank. On the other hand the operations of course has to be done with the NDS rack off, taking care to not damage the hoses and finally paying attention in the handling of the acid and base substances that can cause injury to the operator. For this last, it is recommended that the operator wear gloves and protective glasses before starting with the operations to avoid problems.

Fig. 149 NDS Rack – Tanks

Replacement of Nutrient Solution in the NDS Tank

That operation is required in case it is necessary to change the nutrient solution in one (or both) nutrient solution tank and is done of several steps aimed not only at the replacement of the nutrient solution, but at the washing of the tanks and of the fluidic circuit to remove all the residuals of the old solution. The operation has to be done with all the NDS components off, even if in some phases some pumps have to be activated to promote the flushing of the tubes or the tanks empting. The sequence (of course valid for the two tanks) is described below (only macro steps, the detailed instructions are provided via an ad-hoc procedure):

1. NDS S/S deactivation
2. Connection of the drain pipe line to the pump and configuration of the valves for drainage
3. Activation of the drainage pump to empty the tank from the old nutrient solution

4. Cleaning of the inner part of the Bulk Nutrient Tank (including recirculation pump, thermal coil, and pipes) by hand with tissues
5. Rinsing with fresh water using hose
6. Emptying the tanks again using the drainage pump
7. Washing the tanks and the fluid circuit with bleached water (by means of the activation of the recirculation pump)
8. Removal of the bleached water using the drainage pump
9. Rinsing again with fresh water using hose
10. Emptying the tanks again using the drainage pump
11. Replace the filter
12. Fill the tank with a some fresh water
13. Flush the feeding and the return line activating the High Pressure Pump
14. Empty the tank
15. Fill with other fresh water to remove possible remaining particulate
16. Finally empty the tank using the drainage pump
17. Configure the valves for nominal operations
18. Fill the tank with a stock solution and activate the recirculation pump for solution mixing

The sequence appears to be quite long but in any case, it is not so complex. Some steps could be critical, like for example the deinstallation of the tank sensors in view of the tank cleaning, some other steps could pose same safety issue (like for example the usage of bleached water) or use of water in proximity of powered items. The operator has to take care of these mentioned aspects and will be instructed to take all the safety precautions via dedicated step in procedures.

8.7.4 LED System Maintenance

A monthly check has to be scheduled to verify the cleanliness of the LED's plastic cover. If the clear plastic plate covering the LEDs becomes dirty it should be wiped off with a soft damp cloth. A mild detergent can be used if the plate has fingerprints or similar smudges.

8.7.5 ISPR Maintenance

Several maintenance activities are foreseen for the ISPR rack as follow.

ISPR Subsystem Inspection

The objective of this activity is to perform a periodic inspection of all EDEN ISS subsystems (drawers): ILL / ILR, GCS/ GCT, NDS and PCDH. It is aimed at the verification of the absence of water and/or nutrient solution leakage and to collect info for the definition of corrective actions in case of that occurrence. The activity has to be done after every crop cycle is completed (approx. 3 months) or whenever a leak/failure occurs. The procedure foresees that the visual inspection / drying starts from upper drawers to lower ones in order to avoid that, after a first drying, any given drawer could be wetted by water falling down from the drawers above it. It has to be remarked that every drawer is built with a slightly tilted bottom panel. Hence, any possible water drops falling to drawers bottom panel can slide towards drawer inner front panel and easily detected and removed by the operator. The procedure foresees the following steps (Remark: Only the nominal high level steps are indicated, detailed instructions, as well as the corrective actions to be taken in case of issues, are described in the related procedure).

1. Rack Shutdown (the check operation has to be done with all the subsystems of for safety reason)
2. Disconnection of all the cables hoses from the front panel
3. Illumination Drawers Inspection

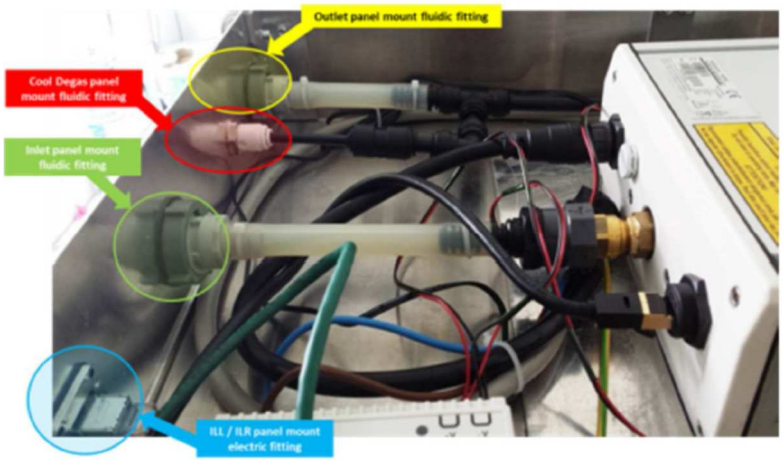


Figure 150: Illumination Drawer Fluidic fittings

a. Removal of the Illumination drawers from the ISPR Rack
b. Removal of the drawers upper lids
c. Drawers inner inspection
d. Closure of the drawer
e. Reinstallation of the drawer inside the ISPR Rack

4. Growth Chambers Inspection

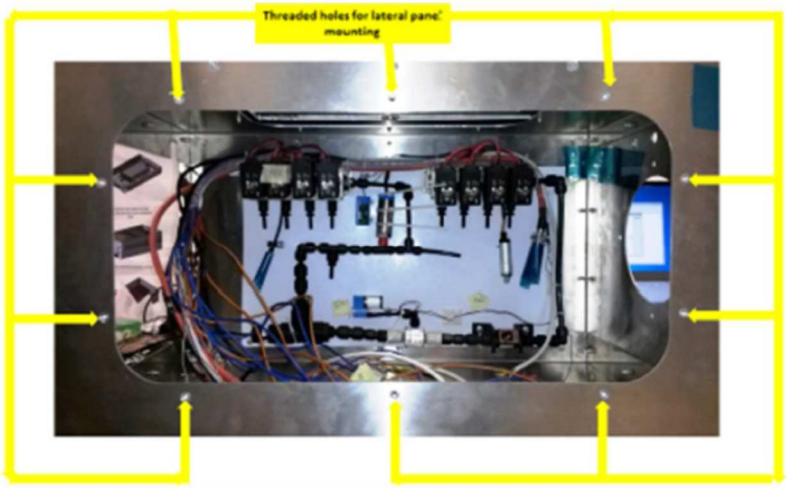


Figure 151: GCT Inner components

a. Extraction of the Drawers until the hard stop
b. Removal of the lateral panels
c. Visual Inspection of all the drawer components
d. Installation of the lateral panel
e. Reinstallation of the Drawers inside the ISPR rack

5. Nutrient Delivery System Inspection

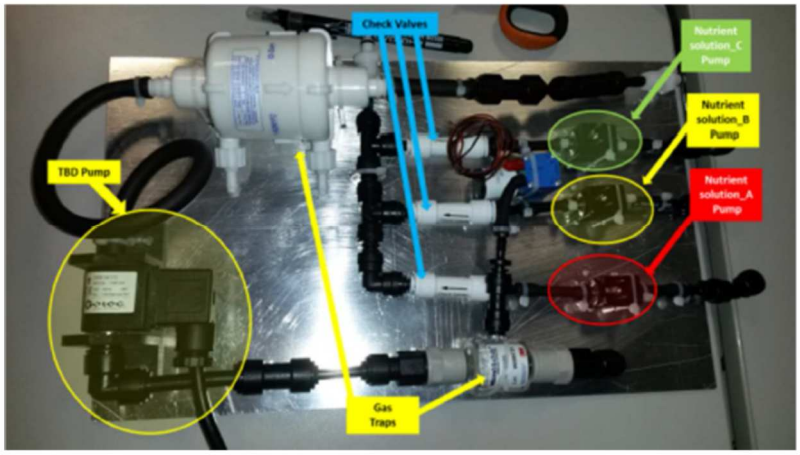


Figure 152: Nutrient Delivery System Components

a. Removal of the NDS drawer from the ISPR Rack
b. Removal of the upper panel from the drawer
c. Removal of the Nutrient tanks and of the support panel in the following sequence
    i. Nutrient tank C
    ii. Support Plate1
    iii. Nutrient tank B
    iv. Support Plate2
    v. Nutrient tank A
    vi. Support Plate3
d. Inspection of the NDS subsystem
e. Reinstallation of the tanks and the support plates (reverse sequence of that in point c)
f. Reinstallation of the upper panel
g. Reinstallation of the drawer inside the rack

6. Power Command & Data Handling Drawer Inspection
    a. Removal of the PCDH drawer form the ISPR Rack
    b. Removal of the drawer upper panel
    c. Inspection of the PCDH Components
    d. Reinstallation of the upper panel
    e. Reinstallation of the drawer inside the ISPR Rack
7. Re-Connection of all the Rack utilities (cables and hoses)
8. Rack activation

ISPR CO2 Bottle Replacement

Figure 153: CO2 bottles inside the lower left side of the Main Utility Module

The objective of this activity is to replace CO2 bottles in the Main Utility Module when they are empty. This activity is required when the CO2 level inside the bottles falls below 1.5 and is done as per the following steps:

1. removal of the front panel on the lower left side of the main Utility Module
2. Verify CO2 pressure < 1.5 bar on both the pressure Gauges and on the Rucola Display
3. Closure of the CO2 outlet valves
4. Disconnection of the CO2 outlet fitting
5. Removal of the CO2 bottles fixations and removal of the CO2 empty bottles
6. Installation of the new CO2 bottles (2) and connection to the CO2 outlet fittings
7. opening and regulation of the CO2 Outlet Pressure Regulation Valves

ISPR Light Panel Replacement

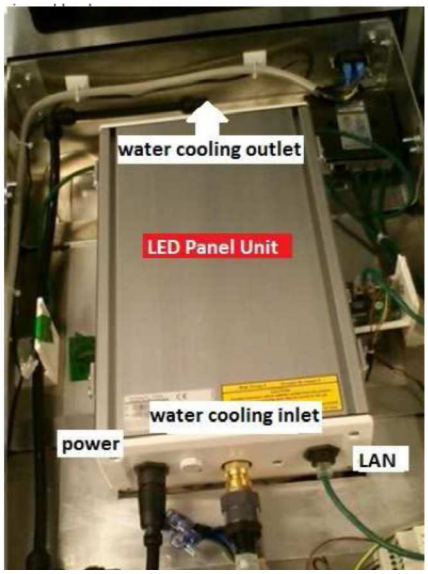


Figure 154: Illumination Drawer Interior

The objective of this activity is to replace the LED panels in one or both the Growth Chamber whenever required. The activity has to be done with the Rack powered off in order to avoid potential electrical shock to the operator and is composed of the following steps:

1. Disconnection of all the cables and hoses from the front panel of the drawer
2. Drawer Removal
3. Water removal for the drawer water cooling circuit
4. Removal of the upper lid cover form the drawer
5. Disconnection of all the hoses and cables from the LED Lamp Unit
6. Installation of the new LED Lamp Unit and connection to the cables and hoses
7. Installation of the Lid cover
8. Installation of the drawer in the rack enclosure and connection of the cables and hoses on the fron panel
9. Activation of the Rack and configuration of the new LED Lamp Unit (assignment of the network parameters)

ISPR NDS concentrated nutrient tanks replacement

Figure 155: Nutrient tanks

This activity is required whenever one or more nutrient tanks are empty. Since it is an activity requiring a huge crew time, it is envisage to replace all the nutrient tanks in one single event even if they are not completely empty. The activity is composed of the following steps

1. Rack deactivation (the activity requires the subsystem off for safety reasons)
2. Removal of cables and hoses to allow drawer extraction
3. Drawer extraction
4. Removal of the Nutrient tanks and of the support panel in the following sequence
    a. Nutrient tank C
    b. Support Plate1
    c. Nutrient tank B
    d. Support Plate2
    e. Nutrient tank A
    f. Support Plate3
5. Installation of the new Nutrient tanks and of the support panels following the reverse sequence
6. Drawer insertion inside the Rack
7. Hoses and cables connection
8. Rack Activation

NDS Pumps replacement

Te objective of this activity is to replace the broken pump located in the NDS and/or GCS and/or GCT. Two pumps systems have to be considered for this maintenance:

A. the pumps located in the NDS drawer as listed in table 12 below

Table 12: NDS Pumps

Pump ID.	Element/Component Name/Description	Qty	Part #
	Nutrient Storage Assy		
01	Conc. Nutrient solution piston pump	3	106921 (ESX04)
02	Nutrient solution delivery piston pump	1	106103(EMX08)
03	Water to nutrient piston pump	1	106103(EMX08)
04	Water delivery piston pump	1	106103(EMX08)
	Water Recovery Assy		
05	Condensate recovery piston pump	1	106103(EMX08)

B. the pumps located in the GCT/GCS module as listed in the table 13 below

Table 13: GCT/GCS pumps

Pump ID.	Element/Component Name/Description	Qty	Part #
	Root Module - GCS		
06	Nutrient solution recirculation Piston Pump	1	106103(EMX08)
	Root Module - GCT		
07	Nutrient solution recirculation Piston Pump	1	106103(EMX08)

The activity is composed of the following step

1. Rack deactivation (the activity has to be done with the Rack off for safety reason)
2. Pump replacement in the NDS

Figure 156: NDS Inner

   a. cables and hoses disconnection from the NDS front panel, and as necessary, to allow the drawer extraction
   b. Removal of the Nutrient tanks and of the support panel in the following sequence
      i. Nutrient tank C
      ii. Support Plate1
      iii. Nutrient tank B
      iv. Support Plate2
      v. Nutrient tank A
      vi. Support Plate3
   c. Replacement of the broken pump
   d. Reinstallation of the Nutrient tanks and of the support panels (reverse sequence of that in step 3)
   e. Reinstallation of the drawer inside the rack
3. Pump replacement in the GCT/GCS

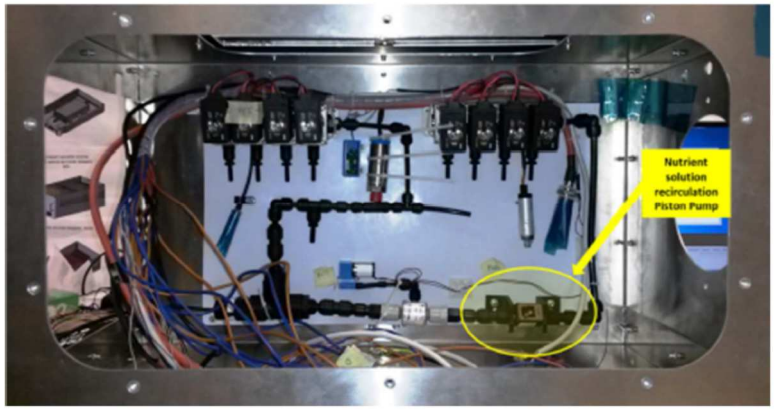


Figure 157: Pump in the GCS

a. Drawer extraction until the hard stop
b. Removal of the lateral panel
c. Replacement of the broken pump
d. Installation of the lateral panel
e. Installation of the drawer inside the Rack

4. Connection of cables and hoses
5. Rack Activation

ISPR NDS D.I. Water Tank Refilling

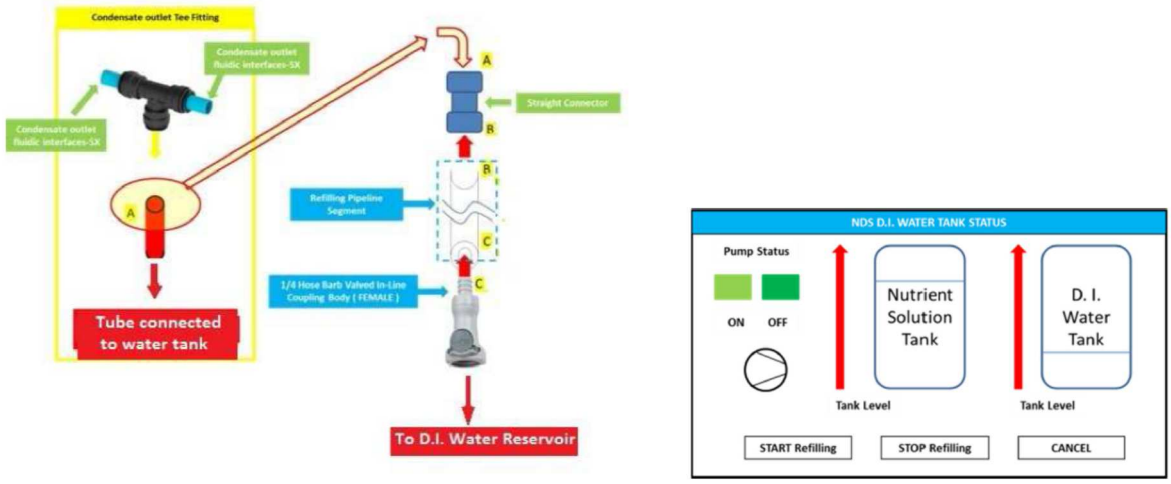


Figure 158: Piping schema

The objective of this activity is to refill the NDS D.I. water tank when it is empty. The NDS D.I. water tank is considered full when D.I. water level is equal or higher than 7 liters and empty when D.I. water level is equal or lower than 350 ml. In this last case the "RUCOLA" software shows a warning message and the operator is requested to take some actions as follow:

1. Operations Stop (but no rack deactivation is required. Indeed we need the rack active to operate the pumps)
2. Connection of the NDS to the external water reservoir via the Refilling pipeline segment
3. Start Refilling operations via dedicated command on the RUCOLA Display
4. Wait until the refilling operations is completed (message got on the RUCOLA Display)
5. Reconfigure the Rack. Detach the refilling pipeline system from the NDS.
6. Restore the operations
7.

Root Module Replacement in GCT

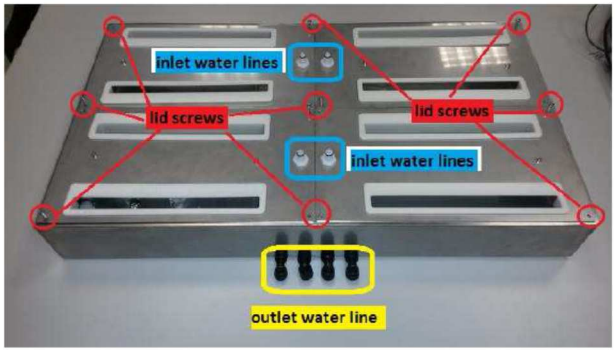


Figure 159: Root Module

This activity is aimed at the replacement of the root module inside the Growth Chamber in case of failure. The activity is composed of the following steps:

1. Rack Deactivation (the operations have to be done with the Rack off as per safety requirements)
2. Cables and hoses disconnection
3. Growth Chamber extraction until the hard stop
4. Lateral panel removal
5. Utilities disconnection from the root module
6. Root Module removal
7. New root module preparation (insertion of the root pillow inside the root module)
8. New root module installation inside the Growth Chamber
9. Installtion of the Lateral panel
10. Growth Chamber Closure
11. Connection of the hoses and cables
12. Rack activation and operation resuming

ISPR PCDH Relays Replacement

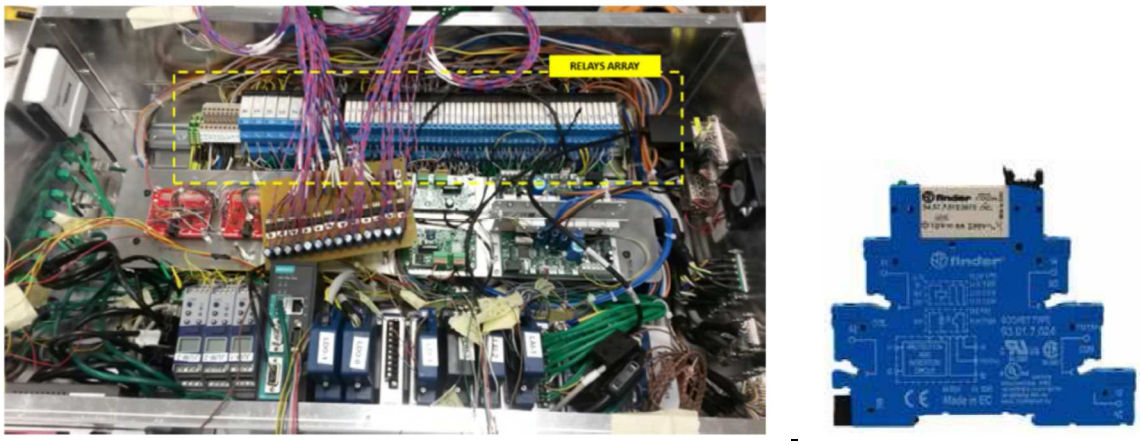


Figure 160: PCDH Inner and relay example

This activity is aimed at replacing one or more relays inside the Power Command & Data Handling Drawer (PCDH).

This procedure has to be used whenever the relay replacement is identified as recovery action from a S/S failure. An offline troubleshooting activities, conducted by the experts panel, will define the relay(s) to be replaced. All the relays are unambiguously identified by labels. Each relays has a number written on its label and operates a single specific component. The activity is composed of the following steps:

1. Rack Deactivation (The activities have to be done with the rack not active for safety requirements)
2. Cables and hoses disconnection as required for PCDH access and removal
3. Extraction of the PCDH Drawer until the hard stop
4. Removal of the upper panel
5. Replacement of the damaged relay
6. Installation of the upper panel
7. Drawer closure
8. Rack deactivation and operations resume.

9 Operative Scenario

9.1Operations Entities

As a baseline, EDEN ISS will be operated by one single on site operator. Five additional entities will be configured as User Home Bases, i.e., will be provided with systems and tools to receive EDEN ISS images and data for real time support and for remote commanding.

The top-level EDEN ISS control network is graphically illustrated in Figure 161.

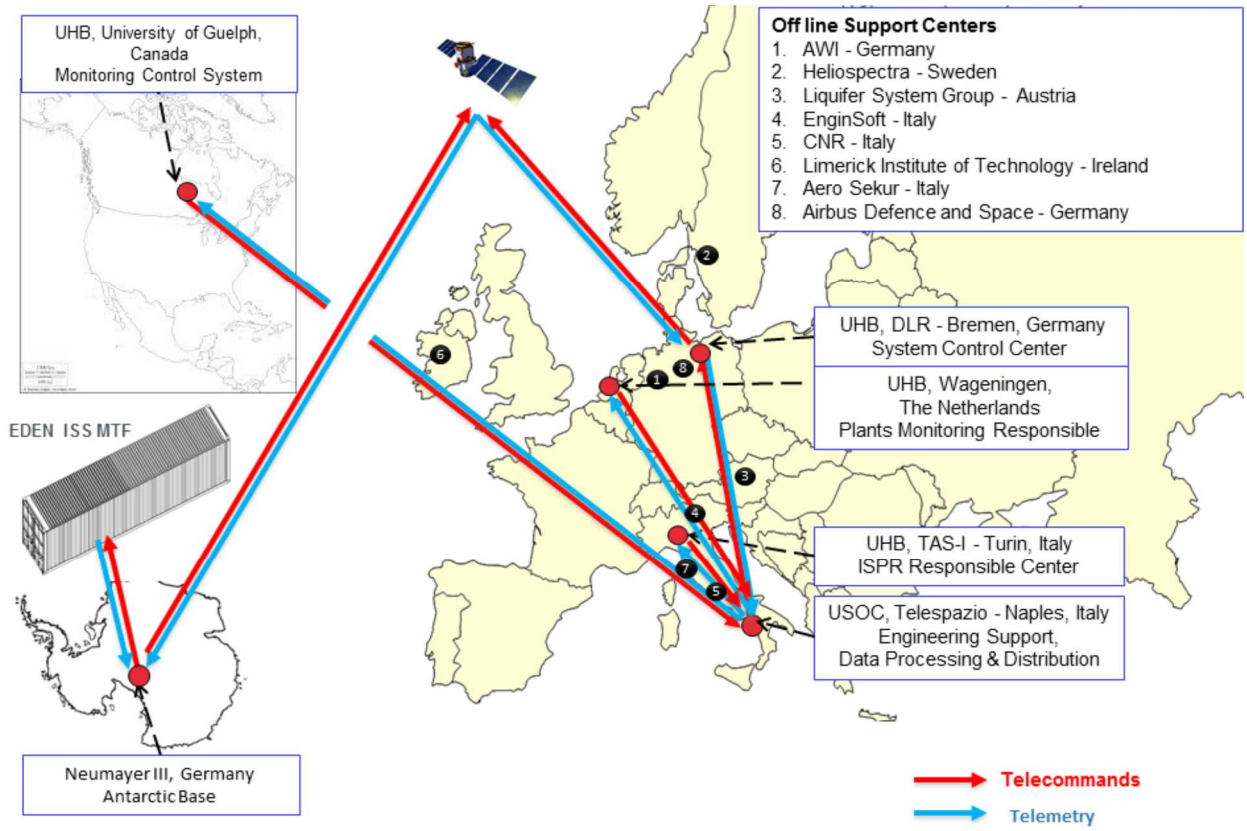


Figure 161: EDEN ISS Network

The **On-Site Operator** will be mainly responsible of the nominal operations as for example sowing/harvesting, plants growth monitoring, sample preparation for off line analysis, S/S management, periodic inspection and maintenance of the critical items (like filters) etc. In case of anomalies it is expected that the on-site operator will manage them as according predefined procedures if any, otherwise he is only requested to take safing actions and rely on the remote experts indication on how to proceed.

It is worth to underline that the service section and the NM-III will be equipped with workstations for MTF and FEG control. In particular the NM-III will be configured as the DLR control room to provide to the on-site operator the same capabilities of DLR, i.e. the capability to interact with the FEG, with the ISPR and with all the related subsystems.

DLR is the EDEN ISS Responsible Center and will accommodate the Mission Control Center, i.e. a control room equipped with:

- 1 Workstation for the MTF Monitoring and Control
- 1 Workstation for the ISPR Monitoring and Control
- 1 Workstation for Image Processing
- 1 Router and Workstation for Data Distribution to the UHB and Data archiving.

DLR is responsible for the all the EDEN ISS Operations. From that reason it will coordinate the entire EDEN ISS team operations, will be responsible for planning activities and first responsible of all the commanding activities. Moreover DLR will be the prime in communication with the on-site operator. It will coordinate all the remote operations as necessary, enabling/disabling the other remote site for commanding. DLR will also coordinate all the troubleshooting activities and recovery actions.

TAS-I is responsible for the ISPR operations and will be configured as UHB. It will be equipped with a console for the ISPR rack monitoring and with the dedicated displays for TM/TC management. In this role and upon coordination with DLR it will be responsible for all the remote operations of the ISPR, including the commanding of the facility. It is the prime in ISPR Rack anomaly handling, troubleshooting activities and recovery actions.

University of Wageningen (DLO) is responsible for the definition of the cultivation plan and of the plant health monitoring. It is configured as UHB, with a workstation for scientific data visualization and image processing tool for plant status monitoring and early detection of plant disease. In case of anomaly detection, DLO will coordinate with DLR all the necessary actions to solve the issue, from the change in system settings (for example light intensity) to the definition of plants medical treatments. If new procedures for anomaly management are required, DLO will provide inputs for procedures development. In addition, being DLO responsible of the crops selection, it is also responsible for the definition of the best conditions for crops cultivation in terms of ambient parameters settings (temperature, humidity, light) and composition of the nutrient solution. On that regards, during the operations preparation phase DLO task is to provide inputs for the definition of the procedures and the cultivation plan.

University of Guelph is responsible for the EDEN ISS Control System. It is configured as UHB with the Workstation and displays to manage the Control system performances and to interact with it via commands if necessary.

TPZ is responsible for user segment monitoring and control. It will be equipped with all the consoles and displays as distributed to the other entities to be able to solve issue and/or to updated the SW applications, including displays as required. In addition TPZ is responsible for procedures development. In this role it will develop and maintain all the procedures needed for the EDEN ISS operations and will participate to the anomaly resolution team, to collect inputs and recommendations for anomaly procedures management.

It is not expected to have people in control rooms looking at the EDEN ISS Telemetry all the time, i.e. working on 24/7 shift scheme, but rather people that, on scheduled event or on demand, are capable to interact with the MTF looking at telemetry and sending commands via dedicated displays and using available procedures. As part of the routine job, the remote operators should daily monitor the EDEN ISS TM (expecially that coming from diagnostic sensors) for a limited time (could be 1 hour or less, or two events of few minutes during office hours) and take logs of the status. Off nominal situations, i.e. troubleshooting activities and malfunctions resolution will be handled as required.

DLR operators have one more task to accomplish, i.e. the management of the interactions with the on-site operator. That will be done twice per day (at the beginning and at the end of the working day as per satellite coverage availability.

The other entities that are not configured as UHB will provide off line support as required. In particular: **AWI** for all the NM-III matter as concerned

Heliospectra for the lighting system

Aero Sekur for the Air Management System

CNR and **Limerick Institute of Technology** for food quality and safety analysis and related evaluation procedures.

Airbus for the E-nose and TransMADDs

Liquifer for System Engineering

DLR-ME for the microbial and psychological investigations

All the UHBs will be connected to DLR for data reception. On the other hand, whenever required, all the commands will pass through DLR to reach EDEN ISS in Antarctica site.

9.2 Operations Phases

Three main phases have to be considered for the EDEN ISS project, each of them requiring ad-hoc developed procedures:

- EDEN ISS Commissioning
- EDEN ISS Nominal operations
- EDEN Planned Maintenance

Anomalies management cannot be considered as operations phases; nevertheless, they have to be considered for the procedures preparation. In particular a fault tree analysis has to be considered within the program in order to foresee in advance, and as much as possible, failure cases to be covered by appropriate procedures

9.2.1 EDEN ISS Commissioning

The Mobile Test Facility will be preconfigured in Germany before delivery to NM-III. Two containers will be assembled with all the subsystems and then shipped to Antarctica. Once on site, the two containers will be transported to the NM-III station, and configured for the final operations. This configuration foresees several steps:

1. EDEN ISS containers, materials and items unload from the ship and load on sled(s)
2. EDEN ISS containers, materials and items transportation to NM-III site
3. EDEN ISS material and items unloaded from sled(s)
4. EDEN ISS containers unloaded from sleds and lifted to the elevated platform
5. EDEN ISS containers assembling
    a. Mechanical connections
    b. Power and data cables connections
    c. Fluidic hoses connections
    d. Mounting of the ladder and of the safety railing
6. EDEN ISS MTF internal configuration
    a. Computers installations
    b. Growth unit installation and connection to NDS supply and return lines
    c. Sensors placement in the FEG and in the growth units
    d. NDS tanks filling with water and other compounds
    e. TCS/AMS/NDS manual valve opening (TBC)
    f. Fixed Camera installation
7. MTF power cable connection to NM-III
8. MTF power on
9. Computers power on
10. Subsystems power on
    a. General facility lighting activation

b. Command and Data Handling System activation
c. Thermal System activation
d. Air Management System activation
e. LED system activation
f. NDS activation
g. Fixed Camera's activation

11. Subsystem's test
    a. General facility lighting system test
    b. Command and Data Handling System test (local)
    c. Thermal System test
    d. Air Management System test
    e. LED system test
    f. NDS test
    g. Image acquisition
    h. Communication System test
        i. Communication with NM-III
12. Robotic Arm test
    a. Automatic operations
    b. Manual operations
    c. Image acquisition
13. ISPR test
14. Ground Segment test
    a. Telemetry and Data distribution to the European Centers
    b. Remote Commanding Capability verification
    c. Videoconference test.

Steps 1, 2, 3 and 4 are under NM-III responsibility and covered by their procedures.

Steps from 4 to 14 needs ad hoc developed procedures.

9.2.2 EDEN ISS Nominal Operations

As soon as the EDEN ISS commissioning has been completed, EDEN ISS will starts its nominal operations. Main objective of EDEN ISS is to grow plants, and that requires the capability to manage the entire growth cycle from seeding to harvesting, and to operate the EDEN ISS subsystems.

1. Plant Management:
    a. Seeding
    b. Plant Transfer to Growth Compartment
    c. Plant Pruning and Training
    d. Plant Health Monitoring
    e. Plant Harvesting
    f. Transport to NM-III
    g. Safety and Quality measurement
        i. Safety sample collection and storage
        ii. Safety Analysis
        iii. Quality sample collection and storage
        iv. Quality Analysis
2. Subsystem Management
    a. Power Distribution and Control
        i. EDEN ISS activation/deactivation
        ii. Subsystems outlet activation/deactivation
        iii. Subsystems power status monitoring
    b. Subsystems status monitoring and control
    c. Service Section Environment parameters setting and change

i. Temperature
ii. Relative humidity level
iii. Air flow rate

d. FEG Environment parameters settings and change
i. Light intensity
ii. Temperature
iii. Relative humidity level
iv. Watering and/or nutrient delivery frequency
v. Water and/or nutrient composition
vi. Water and/or nutrients quantity
vii. CO2 level
viii. O2 level
ix. VOC Level

e. Cameras management
i. Activation/deactivation
ii. Zooming
iii. Acquisition rate

f. Robotic Arm
i. Manual commanding
ii. Automatic operations

g. Videoconferencing System
i. Activation/Deactivation
ii. Configuration for videoconference

3. ISPR Monitoring and Control
a. Mechanical Configuration for plant cultivation
b. Activation/Deactivation
c. Subsystems Monitoring and Control
d. Growth Module Environment parameters settings and change
i. Light intensity
ii. Temperature
iii. Relative humidity level
iv. Watering and/or nutrient delivery frequency
v. Water and/or nutrient composition
vi. Water and/or nutrients quantity
vii. CO2 level

e. ISPR Cameras management

4. Bio-Detection and Decontamination
a. E-Nose Operations
b. Decontamination
c. TransMADDS decontamination

9.2.3 Planned Maintenance

1. FEG Interior and Exterior Cleaning
2. AMS Filters Replacement
3. Thermal Cooling Lines Refill
4. NDS tanks water and nutrients refilling
5. NDS waste water tank emptying
6. NDS Sensor Calibration
7. NDS Cleaning
8. Fresh Water Tank Filling
9. Waste Water Tank Emptying
10. CO2 bottle replacement
11. O2 bottle replacement

12. LED Panel Maintenance
13. Data backup
14. ISPR THC Replacement
15. ISPR TCCS Replacement
16. ISPR CO2 Bottle Replacement
17. ISPR Light Panel Replacement
18. ISPR SubSystem Inspection
19. ISPR NDS Concentrate Nutrient Tank Replacement
20. ISPR NDS tanks Water Refilling
21. ISPR NDS Waste Water Tank emptying

9.2.4 Malfunctions

22. Over temperature
23. Under temperature
24. Air Management System failure
25. NDS failure
26. Lighting System failure
27. Sensors failure
28. Power system failure
29. Control computer failure
30. Building System Failure (Doors, Lighting, electrical, etc,)
31. ISPR Overtemperature/Undertemperature
32. ISP AMS Failure
33. ISPR NDS Failure

10 Procedures Development Process

A procedure consists of a set of instructions to be used by specially trained personnel and/or remote controllers. Whatever system designed for end users is provided with an user guide (or operations manual) that includes the procedures for nominal operations and for high level troubleshooting. Obviously, the complexity of the process to develop good procedures increases with the complexity of the system, requiring in the worst case, the involvement of several experts and the definition of several steps to have a good product.
EDEN ISS is a complex system, not only from technical point of view, but especially because its operative environment, that makes it really close to a space system. For that reason a process shall be defined to ensure the readiness of the procedures for the Antarctica operations, with a clear definition of tasks and responsibilities.

10.1 Procedures Classification

Operational procedures incorporate the tasks needed to operate the mobile test facility, to grow crops and to maintain the related hardware and software systems under both nominal and off-nominal conditions. In view of such a definition, the classification of the operational products is based on four different standpoints: 1) intended user, 2) experiment/project stage, 3) nominal/off-nominal conditions and 4) scope (scientific/engineering). For intended users, ***TPZ*** will consider the procedures for the crew and for the remote users (e.g. scientists or engineers). Another differentiation for the procedures developed will be the time (or better the phases) when they will be, identifying those requested during commissioning, those used during regular operation, those during maintenance and those during failures (see below for further details and a more detailed classification).

1) Intended User: A first categorization according to the intended procedure user can be introduced as follows:

- **On-site Operator procedures**. This task is aimed at the development of the procedures for operating the biological material and the related hardware systems. A first (preliminary) batch of these procedures shall be prepared in time for the on- site operators training.
- **Ground (UHB) procedures**. This task is aimed at the preparation of the procedures for ground personnel operating remotely (science team and Engineering support team). This task shall be accomplished in parallel with the development of the related monitoring/control software (human computer Interface-HCI). A first batch of these procedures will be prepared using the displays (HCI) layout.
- **Ground Displays (HCI)**. The Ground Displays will be developed for monitoring and control of the equipment and experiments execution.

2) Another distinction shall be invoked between Procedures related to the so called Commissioning Phase and ensuing Nominal activities:

- **Commissioning (On-site Operator) procedures**. This task is aimed at the development of the procedures for the installation and setup of both the biological material and the related hardware systems.
- **Commissioning (UHB) procedures**. This task is aimed at the preparation of the procedures for test of the system remote monitoring and control capabilities.
- **Routine (On-site Operator) Procedures**. This task is aimed at the development of the procedures for the routine operations of both the biological material and the related hardware systems
- **Routine (UHB) procedures**. This task is aimed at the preparation of the procedures for the remote operations.

3) Nominal/off-nominal conditions

- ***Nominal procedures*.** This category includes all procedures listed above.
- **Off-nominal procedures**. This task is aimed at the preparation of the procedures to be used in case of system (hardware or software) failures for the identification of the problem root cause (**malfunction or troubleshooting procedures**) and its resolution (**corrective procedures**). Both types can be still distinguished in **on-site operator** and **UHB (ground) procedures**.

4) Scope (scientific/engineering)

- **Scientific procedures.** This category includes all procedures which will be used for scientific purposes (essentially for operating the biological material). Both types can be still distinguished in **on-site operator** and **UHB (ground) procedures**.
- **Engineering procedures**. This category includes all procedures which have an impact on non-biological systems only (hardware and software).

10.2 Procedures Organisation

The procedures will be organized in two books:

- EDEN ISS
- ISPR Rack

With two main chapters:

- On-site Operator
- UHB

Any chapter can contain up to five procedures categories:

1. Commissioning
2. Nominal (i.e. System)
3. Science
4. Planned Maintenance

5. Malfunction

10.3 Procedure Standard

Since the EDEN ISS is looking at future space operations, the procedures will be developed using the so-called PODF (Payload Operations Data File) standard, i.e. the standard used for the development of the procedures for the ISS operations. It is deemed important to adhere to this standard in view of future collaboration with the European Space Agency and/or future operations on ISS of the ISPR Rack.

10.4 Procedures Development and Validation

The procedure development and validation process (see Fig. 162) is an iterative process that is done in parallel to the system realization phase, and having the objective to increase the quality of the procedures as soon as new information is available from the development phase.

The first batch of procedures is prepared starting from documentation. The design report and the user manuals of each subsystem are sufficient to draft a set of procedures that will be presented to a panel of experts for review. The review has the objective to verify if the procedures are correct from a logical and technical point of view, and if they are in line with safety operations.

The number of review session will depend on the number of procedures, on priorities and on the availability of procedures themselves. As far as this last point is concerned it is quite obvious that all the procedures cannot be ready at the same time. In general, the mechanical procedures are ready before the computer based procedures (those to send commands and receive telemetry). These last have as prerequisite the availability of Computers HCI (Human Computer interfaces) that in any case requires an implementation effort and a process similar to the one defined for the procedures.

Comments collected during the review cycle will be discussed in dedicated meeting or teleconference with all the parties, and implemented if agreed.

The first iteration cycle will produce a set of procedures (**preliminary** version) ready to be tested on the HW during test and training. The test is aimed at the validation of the procedures, i.e. at the verification of the correctness of the procedures and on the identification and resolution of possible discrepancies and mistakes. The test will be formally conducted by the procedure author and executed by DLR ground operators (test executor).

This second cycle will produce the **basic** version of the procedures, in principle ready to be used for operations. Nevertheless, other errors or discrepancy could be detected during the other phases of the preparation phase, for example during on-site and ground operators training. Should be this the case, the procedure will be further updated. In any case all the procedures will be promoted to the **final** version before their use in Antarctica operations.

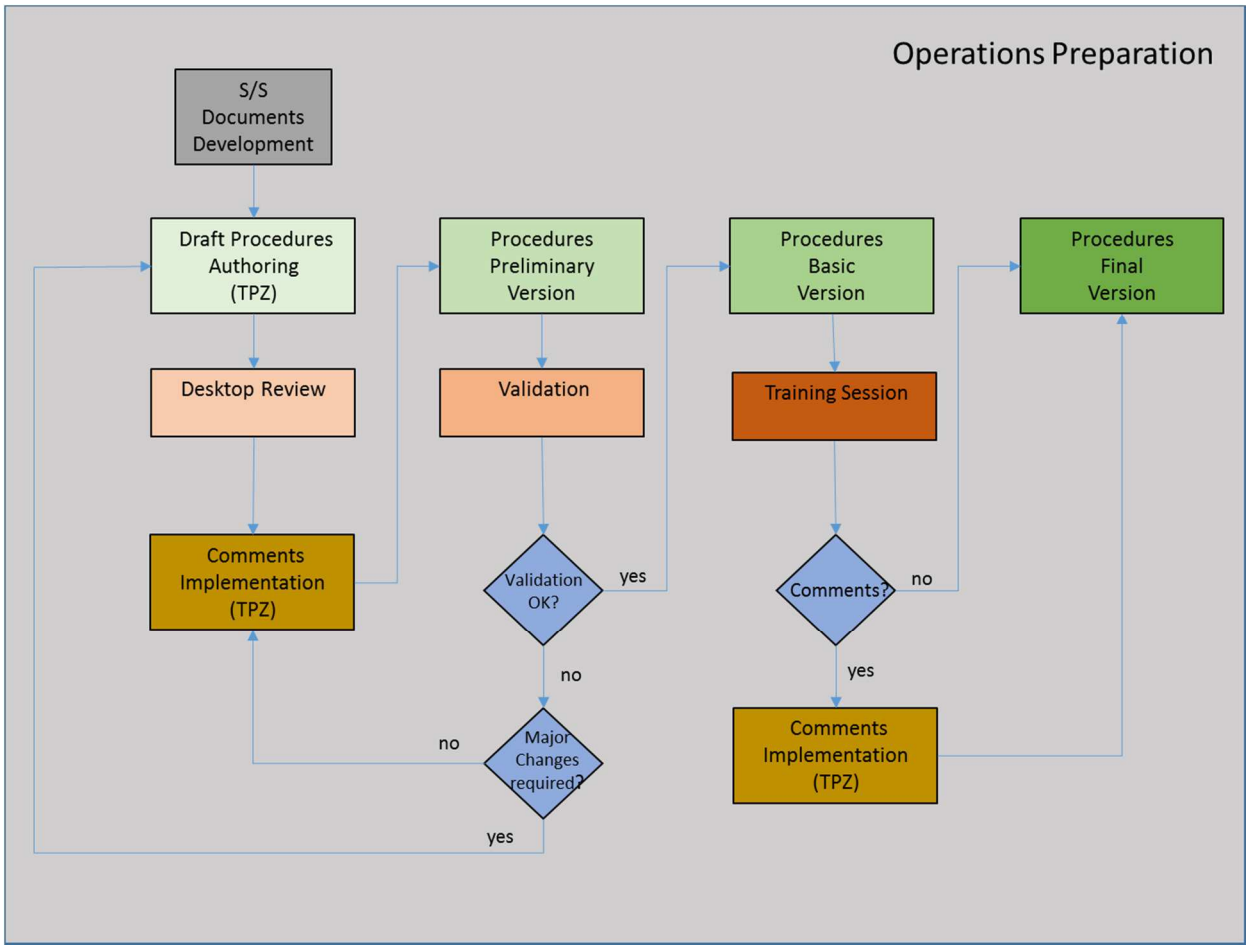


Fig. 162: procedures development and validation process

10.5 Roles and Responsibilities

Procedures authoring, verification and validation process is under the responsibility of TPZ. A Procedure Engineer is appointed for the management of these tasks and for the coordination of all the other activities necessary to accomplish them. Within the EDEN ISS team, he will act as procedures development process lead, being the focal point for the other team members. These last will contribute to the definition of the procedures with their extensive knowledge in the systems (DLR, Aero Sekur, etc.) , plant cultivation and physiology (DLO, CNR), microbiology (DLR-ME) and food quality and safety (CNR, LIT), and will participate to the review process. The review panel is composed by the members of the EDEN ISS team each of them involved for its particular part and/or expertise, and for their tasks within the EDEN ISS project. It is not expected that all the team members will participate in all the review sessions. The Procedure Engineer will select the right persons based on the procedure content and expertise requirement (as example, the responsible of the lighting system will be not called to review a procedure for the NDS system management). Nevertheless it is deemed necessary to have in the review as mandatory participants the EDEN ISS System Engineer and the person in charge of the Antarctica operations. Below the reference:

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10.6 Procedures List

A preliminary list of procedure is provided below. At this stage, this list cannot be the final one since many information's are not or partially available. The list is for sure missing some procedures, some listed procedures could be merged or combined, other could be split in more than one procedure, other deleted, and therefore several changes are expected. In spite of that, this list is providing a good picture of what will be developed and how it will be organized.

10.6.1 EDEN ISS Book

#	Nr	Title	Book	Chapter	Category
1	1.100	MTF Installation at NMII	EDEN ISS	Crew	Commissioning
2	1.110	MTF Internal Configuration	EDEN ISS	Crew	Commissioning
3	1.130	MTF Activation and Checkout	EDEN ISS	Crew/UHB	Commissioning
4	1.160	Plant Health Monitoring Sytem Check-out	EDEN ISS	Crew/UHB	Commissioning
5	1.200	Ground Network Setup	EDEN ISS	Crew/UHB	Commissioning
6	2.000	EDEN ISS Daily System Check	EDEN ISS	Crew/UHB	Nominal
7	2.100	Plant Sowing	EDEN ISS	Crew	Nominal
8	2.105	Plant Thinning	EDEN ISS	Crew	Nominal
9	2.110	Plant Transfer to Growth Trays	EDEN ISS	Crew	Nominal
10	2.120	Crop Management	EDEN ISS	Crew	Nominal
11	2.130	Plant Harvesting	EDEN ISS	Crew	Nominal

12	2.200	FEG Configuration for Plant Growth	EDEN ISS	Crew	Nominal
13	2.500	Videocameras Configuration For Plant Monitoring	EDEN ISS	Crew/UHB	Nominal
14	2.510	EDEN ISS datalog and Images Automatic Transfer to MCC	EDEN ISS	Crew/UHB	Nominal
15	3.210	Growth Media Preparation for Safety Analysis	EDEN ISS	Crew	Science
16	3.211	Samples Collection and Storage for Safety Analysis	EDEN ISS	Crew	Science
17	3.212	Safety Analysis - Vial Operations	EDEN ISS	Crew	Science
18	3.220	Sample Collection and Storage for Quality Analysis	EDEN ISS	Crew	Science
19	3.230	Quality Measurement_Refractometer Operations	EDEN ISS	Crew	Science
20	3.231	Quality Measurement_Penetrometer Operations	EDEN ISS	Crew	Science
21	3.232	Quality Measurement_Colourimeter Operations	EDEN ISS	Crew	Science
22	2.233	Quality Measurement_Clorophylmeter Operations	EDEN ISS	Crew	Science
23	3.234	Quality Measurement_Nitrate Ion Meter Operations	EDEN ISS	Crew	Science
24	3.300	E-Nose Operations	EDEN ISS	Crew	Science
25	3.310	Microbial Sampling _micro	EDEN ISS	Crew	Science
26	3.311	Microbial Sampling _molecular	EDEN ISS	Crew	Science
27	3.312	Microbial Sampling _liquid	EDEN ISS	Crew	Science
28	3.320	TransMADD Decontamination	EDEN ISS	Crew	Science
29	4.100	AMS Filters Replacement	EDEN ISS	Crew	Maintenance
30	4.150	Thermal Cooling Lines refill	EDEN ISS	Crew	Maintenance
31	4.200	Nutrient Distribution System Bulk Solution Tank Refill	EDEN ISS	Crew	Maintenance
32	4.210	NDS waste water tank emptying	EDEN ISS	Crew	Maintenance
33	4.220	NDS Sensors Calibration	EDEN ISS	Crew	Maintenance
34	4.300	Fresh Water Tank Filling	EDEN ISS	Crew	Maintenance
35	4.310	Waste water tank emptying	EDEN ISS	Crew	Maintenance
36	4.400	LED Panel Maintenance	EDEN ISS	Crew	Maintenance
37	5.100	Overtemperature/Undertemperature Management	EDEN ISS	Crew	Malfunction

38	5.200	AMS Failure Management and Repair	EDEN ISS	Crew	Malfunction
39	5.300	NDS Pump Failure Management And Repair	EDEN ISS	Crew	Malfunction
40	5.400	Sensor Failure Management and Repair	EDEN ISS	Crew	Malfunction
41	5.500	Building System Failure Management and Repair (doors, lighting, electrical	EDEN ISS	Crew	Malfunction
42	5.600	NDS pH and EC setting failure	EDEN ISS	Crew	Malfunction

10.6.2 ISPR Book

#	Nr	Title	Book	Chapter	Category
1	1.120	ISPR Configuration	ISPR Rack	Crew	Commissioning
2	1.140	ISPR Rack Activation and Checkout	ISPR Rack	Crew/UHB	Commissioning
3	2.300	ISPR Configuration for Plant Growth	ISPR Rack	Crew	Nominal
4	3.410	ISPR Nutrient solution sample collection	ISPR Rack	Crew	Science
5	3.420	ISPR Air sample collection	ISPR Rack	Crew	Science
6	4.510	ISPR THC Replacement	ISPR Rack	Crew	Maintenance
7	4.520	ISPR TCCS Replacement	ISPR Rack	Crew	Maintenance
8	4.530	ISPR CO2 Bottle Replacement	ISPR Rack	Crew	Maintenance
9	4.540	ISPR Light panel replacement	ISPR Rack	Crew	Maintenance
10	4.550	ISPR Subsystems inspection	ISPR Rack	Crew	Maintenance
11	4.560	ISPR NDS concentrated nutrient tanks replacement	ISPR Rack	Crew	Maintenance
12	4.561	ISPR NDS Pumps Replacement	ISPR Rack	Crew	Maintenance
13	4.570	ISPR NDS tanks water refilling	ISPR Rack	Crew	Maintenance
14	4.580	ISPR NDS waste water tank emptying	ISPR Rack	Crew	Maintenance
15	4.590	ISPR Root Module Replacement ADDED	ISPR Rack	Crew	Maintenance
16	4.600	Relay Replacement ADDED	ISPR Rack	Crew	Maintenance

17	5.610	ISPR Overtemperature/ Undertemperature management	ISPR Rack	Crew	Malfunction
18	5.620	ISPR AMS failures management	ISPR Rack	Crew	Malfunction
19	5.630	ISPR NDS pumps failure management	ISPR Rack	Crew	Malfunction
20	5.640	ISPR Illumination system failure management	ISPR Rack	Crew	Malfunction

11 Displays Development

As seen in the EDEN Operations Section, the system activities of EDEN ISS will be conducted using the Argus Displays. The Argus EDEN ISS display have been divided into logical “groups” or “tabs”, with the possibility to display a lot of information. To help the operator to easily interact with the MTF, the necessary information (in terms of Telemetry Items, or Commands) have been be grouped together as follow (fig. 107):

- ATMOSPHERE MANAGEMENT SYSTEM
  - SERVICE SECTION
  - FUTURE EXPLORATION GREENHOUSE
- THERMAL CONTROL SYSTEM
- POWER DISTRIBUTION SYSTEM
- LED LIGHTING SYSTEM
  - TEMPERATURE OVERVIEW
- NUTRIENT DELIVERY SYSTEM
  - BULK NS TANK1 CONTROL
  - BULK NS TANK2 CONTROL
  - IRRIGATION SCHEDULE
- COMMUNICATIONS
  - TC1 MODBUS NETWORK
  - TC1 IO NETWORK
  - TC2 IO NETWORK
- ALARMS OVERVIEW

All the greenhouse subsystems will be managed via such a tool with the exception of the ISPR rack that has its own displays developed using LabVIEW.

The control philosophy is more or less the same. Some main displays are used for high-level control of the ongoing operations with in addition the possibility to recall S/S displays to deeply check dedicated Telemetry. In particular the displays can be listed as follow:

- MAIN WINDOW
- ILLUMINATION SYSTEM LEFT
- ILLUMINATION SYSTEM RIGHT
- NUTRIENT DELIVERY SYSTEM
- GROWTH CHAMBER TALL
- GROWTH CHAMBER SHORT

- POWER, COMMAND AND DATA HANDLING
- RELAYS STATUS
- SET PARAMETER WINDOW

Form this displays it is possible to open further subdisplay as for example the GROWTH CHAMBER CONTROL PANEL

11.1 Displays Development and Validation

The display validation will follow a similar process as described for the procedure. The preliminary version will be proposed for an internal desktop review, and then tested and validated in parallel to the procedures.

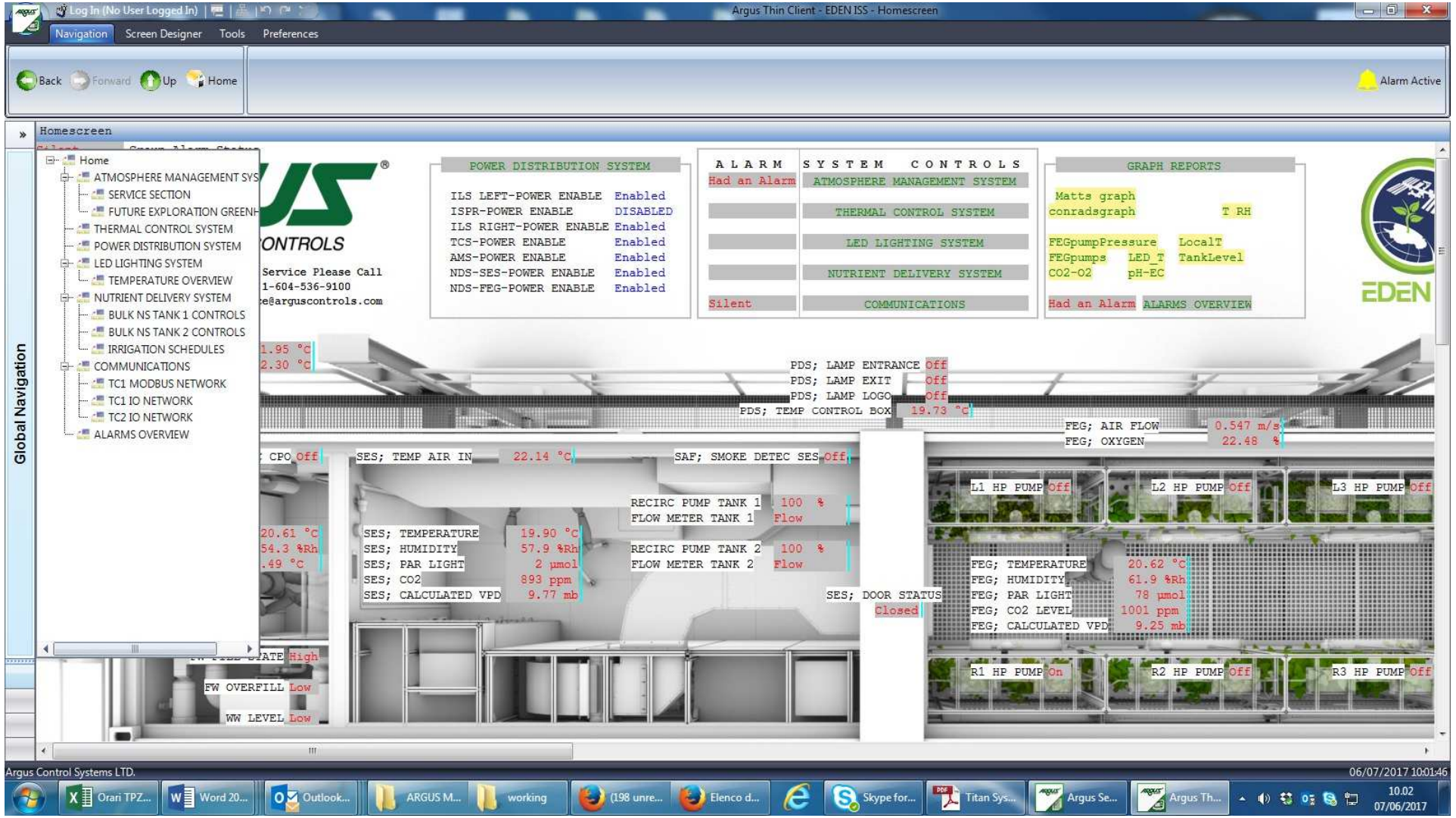

Figure 163: ARGUS Main display with Navigation Menu

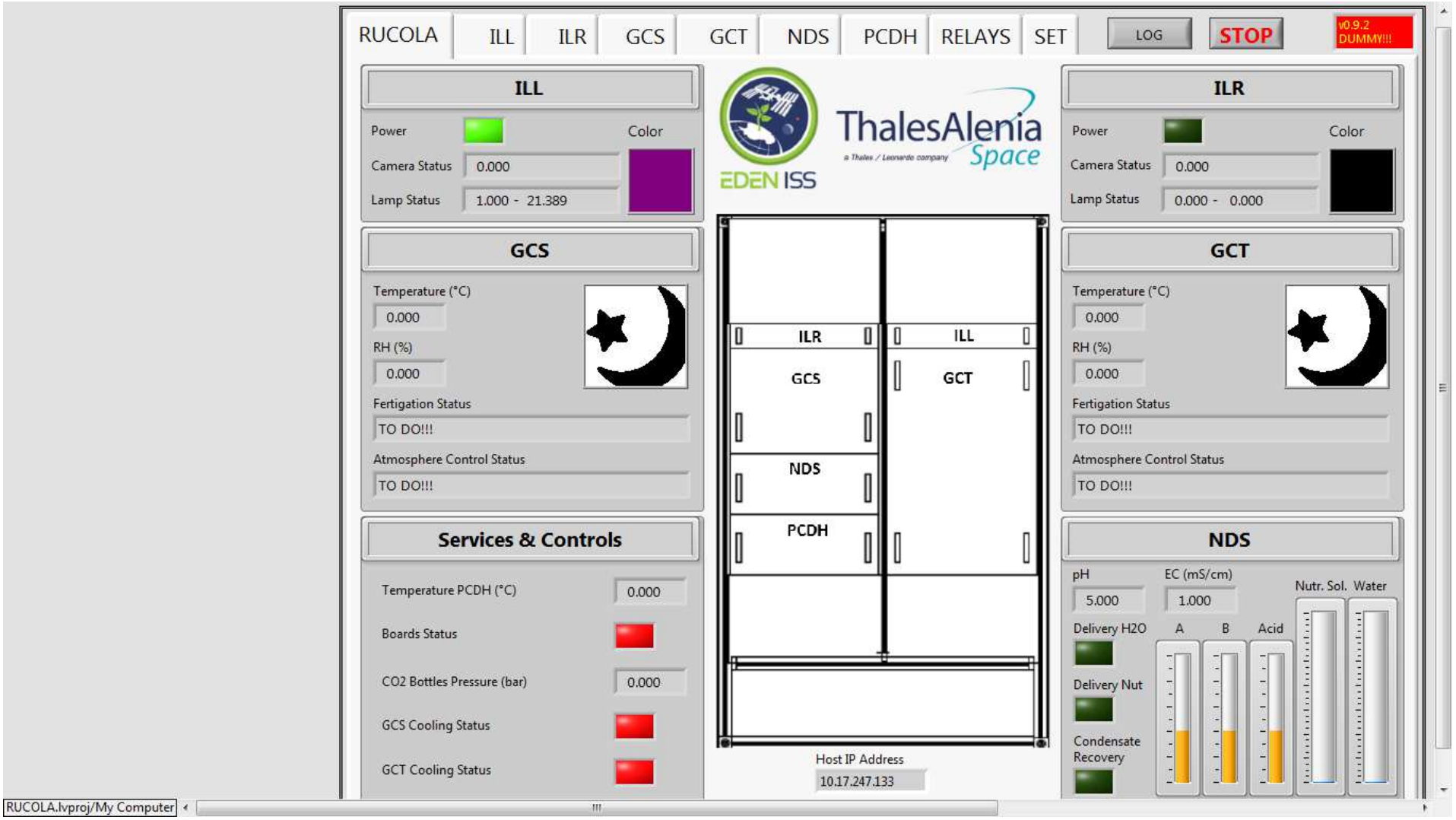

Figure 164: ISPR Main Display

12 Specific Tasks

The objective of this chapter is mainly to list the main task to be performed to finalise the procedures and Displays in order to have them ready for the Antarctica operations. The task will be described not only in terms of what to do, but also in terms of inputs needed and deliverables.

WP	Task Name	Inputs needed	From Who	Deliverables
2.5	EDEN ISS Documentation Analysis	• EDEN ISS Design Report • EDEN ISS S/S Design Reports • Others (TBD)	EDEN ISS Team	N/A
2.5	EDEN ISS Ops Mode and Test Plan Development	• EDEN ISS Design Report • EDEN ISS S/S Design Report	EDEN ISS Team	EDEN ISS Ops Mode and Test Plan (remark: This document has to be considered a **living document** to be updated as necessary)
2.5	Procedures Draft	• EDEN ISS Design Report • EDEN ISS S/S Design Report • EDEN ISS Operations Modes and Test Plan	EDEN ISS Team	Procedures Draft
2.5	Procedure (Preliminary Version) development and verification	• Procedure Draft • EDEN ISS Design Report • EDEN ISS S/S Design Report • EDEN ISS Operations Modes and Test Plan • Engineering Procedures • Preliminary Displays (ARGUS?)	EDEN ISS Team	EDEN ISS Procedures (Preliminary Delivery)
4.5	Procedures (Final Version) Development and validation	• Preliminary Procedures • Final Displays (ARGUS?) • EDEN ISS HW/SW	TPZ	
2.5	Ground Displays Layout Design	• EDEN ISS Design Report • EDEN ISS S/S Design Report • EDEN ISS Operations Modes and Test Plan	UoG	Ground Display Layout

2.5	Displays Preliminary version development and verification	• Displays Layout	UoG	Ground Displays Basic
4.5	Ground Displays Final Version Development and Validation	• Preliminary Ground Displays • EDEN ISS HW/SW • UHB Implemented	UoG)	Final Ground Displays
4.5	Malfunction procedures final version development and validation	• EDEN ISS Design Report • EDEN ISS S/S Design Report	EDEN ISS Team	Malfunction procedures
		• EDEN ISS Operations Modes and Test Plan	TPZ	

12.1 Schedule

The schedule below is based on the assumption that all the required inputs as described in par. 5 are provided in time. Critical Items are:

- EDEN ISS Design Report
- EDEN ISS S/S Design Report
- EDEN ISS Displays
- EDEN ISS HW and SW

WP #	WP Title	Objective	Start	End
2.5	Ops Procedures and Displays Definition	*Initial ops procedures for all hardware and ops*	Oct 1, 2015	Sep 30, 2016
4.5	Ops Procedures and Displays Test and Training	*Test and validation of ops procedures* *Update of ops procedures based on testing*	Jan 1, 2017	Nov 30, 2017
5.3	Ops Procedures and Displays Maintenance	*Update of ops procedures based on actual Antarctic deployment*	Jan 1, 2018	Nov, 2018

13 EDEN ISS Operations Planning

EDEN ISS planning are under DLR responsibility with the support of the scientific team. A high-level plan will be developed much before the start of the operations, to provide the picture of the entire EDEN ISS test campaign.

Two weeks before the start of the Antarctica operations, the planning will enter in its executive phase, with the definition of the so called Monthly Look Ahead Plan and the Weekly Look Ahead Plan. The executive plan has the objective to detail what to do, to define the needed resources, and to define who is doing what.

The Monthly Look Ahead Plan (MLP) will provide a forecast of the activities to be done in the next month starting from two weeks after the plan itself is released. It is still a high level plan, defining a high level sequence of activities and build with the contribution of all the parties. It is updated every week, with the addition of a new week of activities and is released on Tuesday.

The Weekly Look Ahead Plan (WLP) will provide the schedule of the activities to be done on week after the plan itself is released. It contains some important details on the activities to be done like the start time, the duration, and who is doing what It is prepared every week from the MLP and it is released on Friday. The WLP in principle freeze what has to be done on next week, but on the other hand it can be updated if necessary.

That is done with the development of the Daily Planning. Every day the detailed plan for the day after is prepared, with the addition of the missing information, like procedures to be used, items to be retrieved etc.

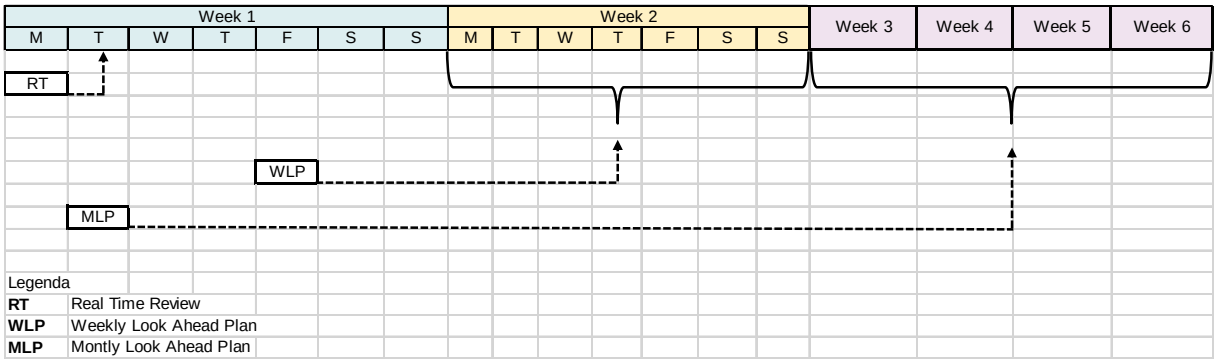

Fig. 165: Planning Process

The planning iteration will be managed via teleconference. A weekly telecon, having as participants all the EDEN ISS team representatives, will be held on Tuesday with the objective to report on the ongoing activities, track any anomalies and define the look ahead plans. The telecon will be led by DLR that has also the responsibility to manage the MLP updates and to prepare it according the inputs coming from all. In addition, DLR will prepare the WLP for the next week activities. If not deemed necessary the telecon can be canceled in favor of email exchange. The planning will be transferred to the NMIII station via email to the EDEN ISS operators and discussed in the morning telecon with crew (telecons will become less frequent after several weeks/months as a period of more nominal operations of the MTF will be reached).

13.1 Planning tool

The planning will be managed with an xls file containing several sheet:

- Overall plan

- Montly Activities
- Weekly Activities
- Daily Activities

Each of them is derived from the previous, with the addition of more information and details. In the following the proposed tools:

Monthly activities			
week 1	**Activities**	**Crew/UHB**	**Notes**
Mon 18 Jan.			
Tue 19 Jan			
Wed 20 Jan			
Thu 21 Jan			
Fri 22 Jan			
Sat 23 Jan			
Sun 24 Jan			
week 2	**Activities**	**Crew/UHB**	**Notes**
Mon 25 Jan.			
Tue 26 Jan			
Wed 27 Jan			
Thu 28 Jan			
Fri 29 Jan			
Sat 30 Jan			
Sun 31 Jan			
week 3	**Activities**	**Crew/UHB**	**Notes**
Mon 01 Feb.			
Tue 02 Feb			
Wed 03 Jan			
Thu 04 Feb			
Fri 05 Feb			
Sat 06 Feb			
Sun 07 Feb			
week 4	**Activities**	**Crew/UHB**	**Notes**
Mon 08 Feb.			
Tue 09 Feb			
Wed 10 Jan			
Thu 11 Feb			
Fri 12 Feb			
Sat 13 Feb			
Sun 14 Feb			

Fig.166: Montly Activity Plan

Monday

Activity no.	Activity name	Short description	Crew/UHB	Start time	Duration
D01	water pressure	check water pressure in line xyz			2 min.
D02					
…					

Tuesday

Activity no.	Activity name	Short description	Crew/UHB	Start time	Duration
W01	trash	collect all trash in the MTF and bring it to NM III waste processing/storage			60 min.
W02					
…					

Wednesday

Activity no.	Activity name	Short description	Crew/UHB	Start time	Duration
M01	exchange filter xyz	exchange HEPA filter in AMS; discard old one and integrate clean one			30 min.
M02					
…					

Fig.167: Weekly Look Ahead Plan

Date:							
Activity no.	Crew/UHB	Start Time (GMT)	Duration (hh:mm)	Activity name	Short description	Items required	Procedure
D01	Crew	9.00	0.05	water pressure	check water pressure in line xyz		
D02							
…							

Fig.168: Daily Activities