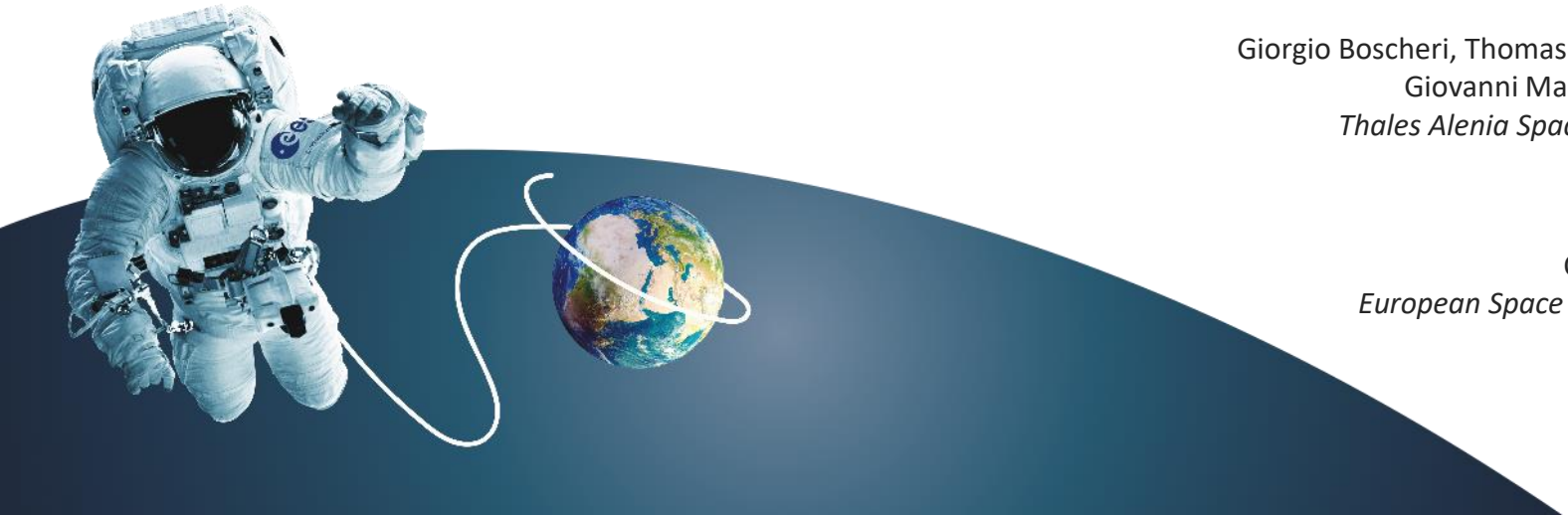
MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

CREATING A CIRCULAR FUTURE

PFPU – Microgravity Precursor Food Production Unit development status



Giorgio Boscheri, Thomas Fili and Giovanni Marchitelli
Thales Alenia Space Italia

and

C. Paille
European Space Agency


A little bit of context…
FROM EARTH TO DEEP SPACE
8 000 KM
800 KM
700 KM
400 KM

The forge of the Lunar Gateway

Leading the development of the International Habitat I-HAB & logistic module ESPRIT

Supporting the creation of the first Gateway Module, HALO

Building the backbone of the ORION Spacecraft

World Leader in LEO Orbital Infrastructures

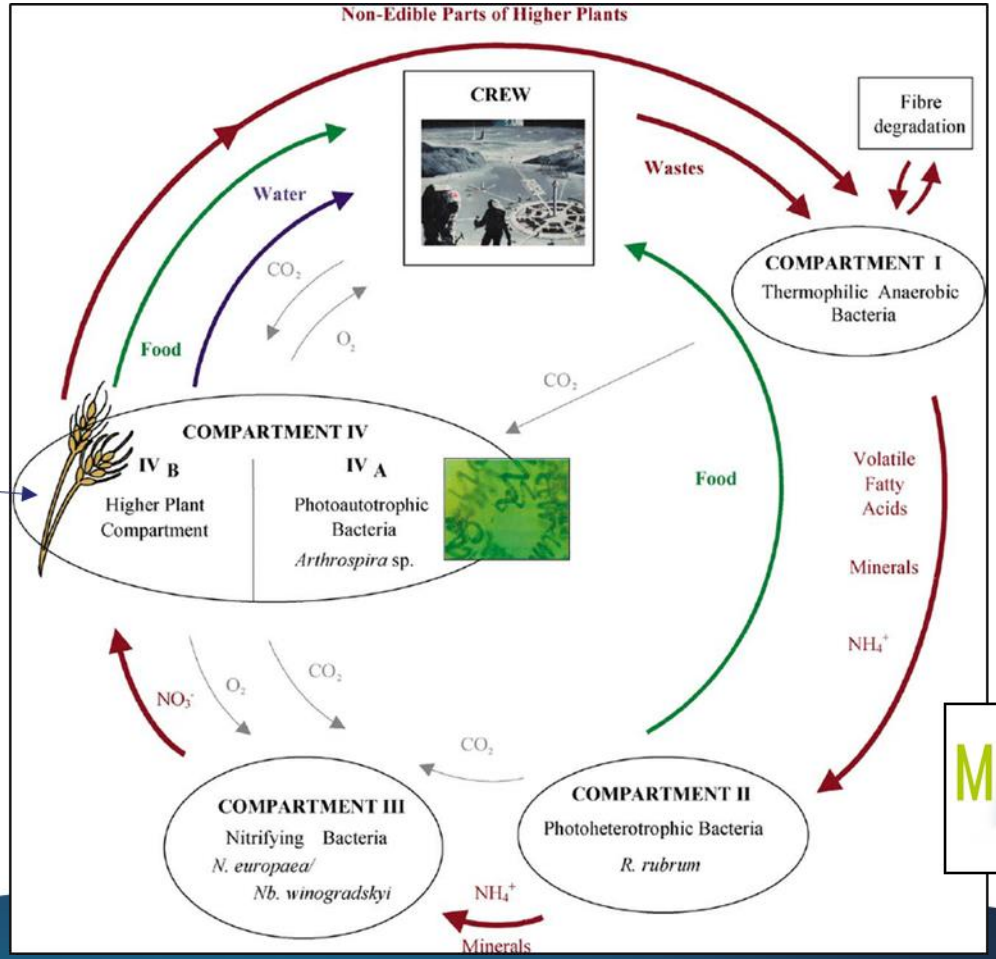
Manned and unmanned pressurized modules

Building and supplying the ISS

Contributing to the creation of the first commercial space station, Axiom

Enabling easy access to Space with re-entry vehicles

MELISSA



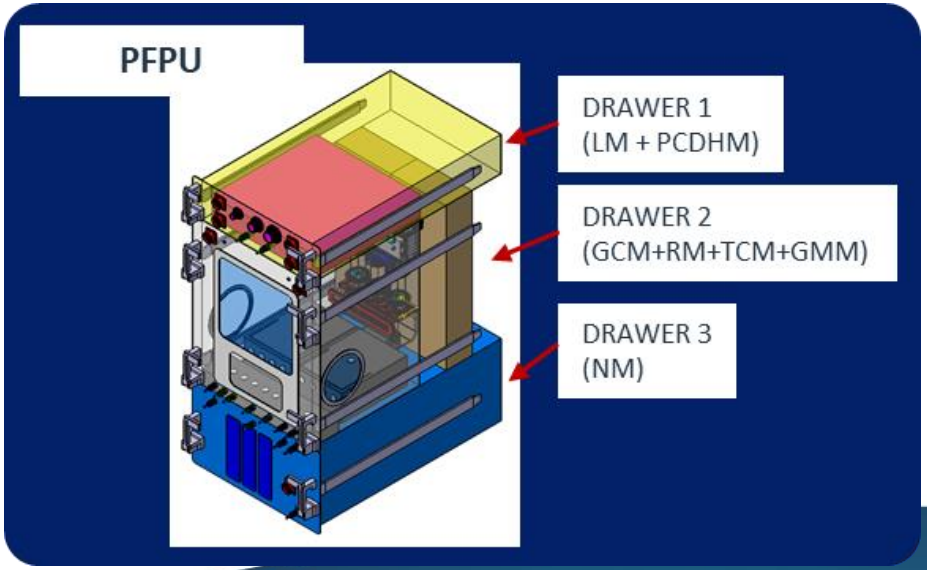
MELISSA

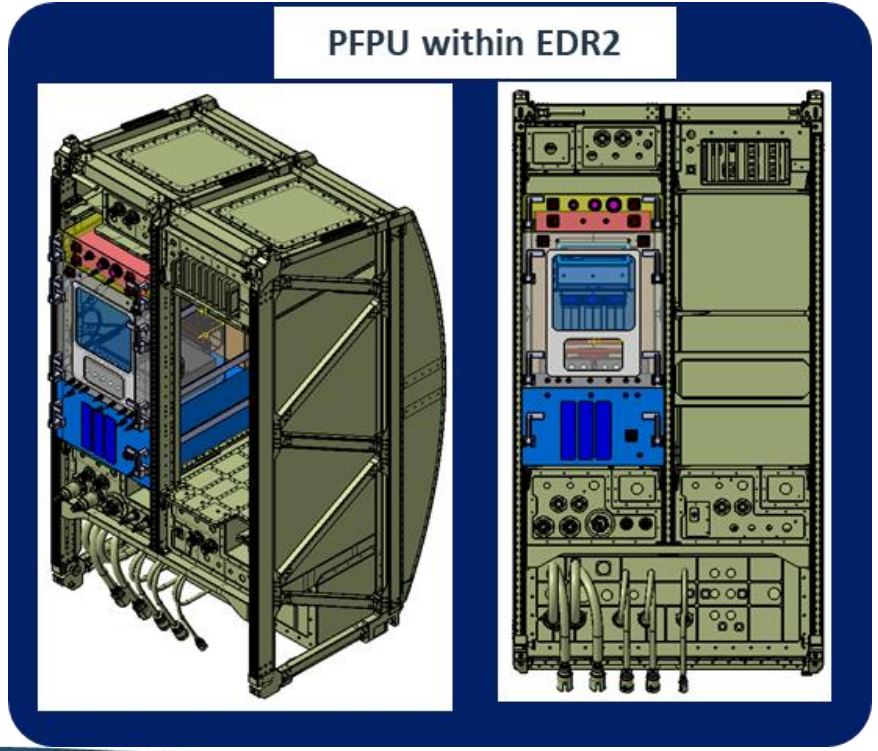
PRESENTATION CONTENT

1. PFPU SYSTEM OVERVIEW
2. BREADBOARD MODEL (BBM)
   Subsystems development status
3. FUTURE PERSPECTIVES
4. ACKNOWLEDGMENTS

WHAT IS PFPU

- **Demonstrator** for reliable production of tubers (potatoes) on the **ISS**
- Realized as an Experimental Insert for **EDR MK II**
- Consisting into **3 drawers**





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YES, WE ARE TALKING ABOUT SPACE POTATOES!

We are growing tubers "Not because is easy, but because is hard" cit. ☺

THE PFPU TEAM

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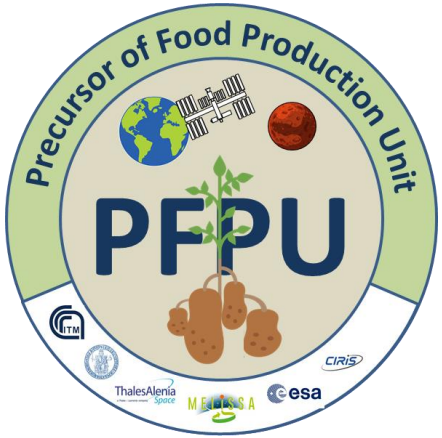


ThalesAlenia Space

Prime Contractor
Study Management
System Design
Consolidation
Nutrient Module TRL Increment
New Modules Development
- Temperature Control
- Growth Chamber
- Illumination
- Gas Management
- Power, Command & Data Handling

Giorgio Boscheri
Giovanni Marchitelli
Thomas Fili

Root Module Study
- Agronomical aspects
- Testing with tubers

Stefania De Pascale
Youssef Rouphael
Mario Paladino
Antonio Pannico

ITM

Membrane Technologies Development
- Condensate Separation Unit
- Water Degassing Unit

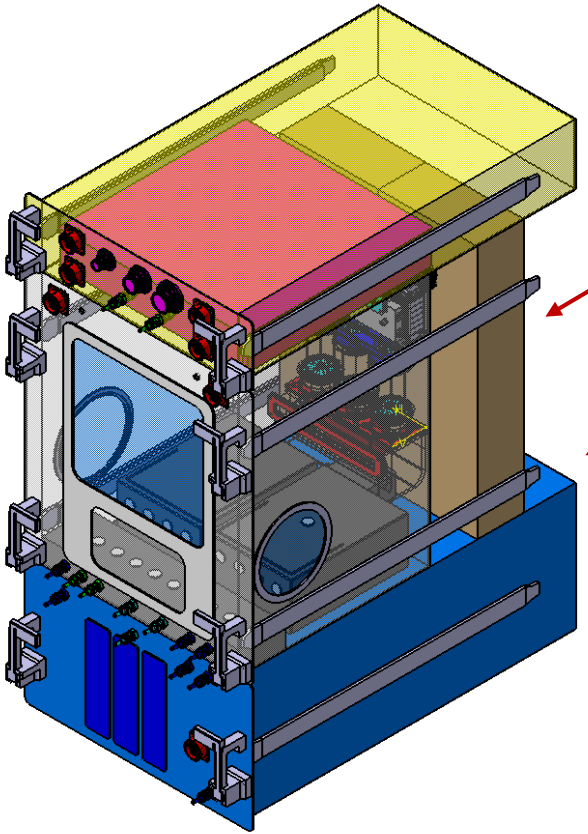
Giuseppe Barbieri
Adele Brunetti
Lidietta Giorno

CIRIS

Root Module Design
- Design Update

Carina Helle Berg
Ann-Iren Kittang Jost
Øyvind Mejdell Jakobsen
Kai Arne Kristiansen
Achim Gerstenberg
Irene Karoliussen

WHAT IS PFPU



Peculiarities wrt similar facilities:

- Long growth cycle (≈100days)
- Large water storage (incl. recovered condensate)
- In-situ nutrient solution mixing
- Glove box + pass-box access
- Size constrained by flight opportunity
- Designed for tuber growth

LM	Illumination Module
PCDHM	Power Command and Data Handling Module
GCM	Growth Chamber Module
RM	Root Module
TCM	Temperature and humidity Control Module
GMM	Gas Management Module
NM	Nutrient Module

PFPU PROGRAMMATIC STATE OF THE ART

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TAS performed already 3 study phases (last still ongoing):

- 2016-2018
  System requirements baseline, system engineering plan and demonstration strategy
  In-depth study, **breadboards manufacturing and thorough testing** of selected **critical modules** (Nutrient Module - NM, Root Module - RM, Microbial Contamination Control Module - MCCM)

- 2018-2020
  Consolidate the operational concept,
  Further development of critical modules

- 2021-2023
  Further demonstrate the technologies that are sensitive to the launch and space environment
  Mature the system design through the development and **testing** of an **integrated breadboard** (i.e. form, fit and function for ground demonstration)
  Re-evaluation of the preliminary system requirements and space demonstration strategy

PFPU SHORT TERM TASKS

- April – June 2022
  Manufacturing of the PFPU system breadboard

YOU ARE HERE

- July – November 2022
  PFPU system breadboard single and sub-aggregated modules testing
- December 2022
  PFPU system breadboard testing without crops
- January – June 2023
  PFPU system breadboard testing with crops
- July – October 2023
  PFPU design update and system requirements consolidation
  Consolidate early techno µg demonstration (e.g. parabolic flights)

PFPU breadboard representativeness of flight HW

Module	Key Components	Architecture	External envelope	I/F Typology	I/F Position	HW layout	Surface finish
RM	R	R	R	R	R	R	R
NM	R	R	NR*	R	NR	NR	NR
LM	PR	R	R	R	R	PR	R
GCM	R	R	R	R	R	R	R
GMM	PR	PR	R	PR	R	PR	NR
TCM	R	R	R	PR	R	R	NR
PCDHM	PR	PR	NR**	R	NR	NR	NR

JUSTIFICATIONS
- Illumination quality
- Air management quality
- Irrigation quality
- Crew operations feasibility
- Impact of boundary conditions on product quality
- Rapid implementation of design changes
- Coverage of EDR2 and/or EGSE functionality
- Safety of operation according to CE regulations

LEGEND

R	Representative
PR	Partially Representative
NR	Not Representative

* NM BBM is not representative for external envelope since it is not relevant to BBM system performance, as well as because reservoirs structural design revision may impact current item envelopes

** PCDHM BBM is not representative for external envelope since it includes additional functions with respect to the flight unit, while also including a not envelope-optimized but more flexible PLC

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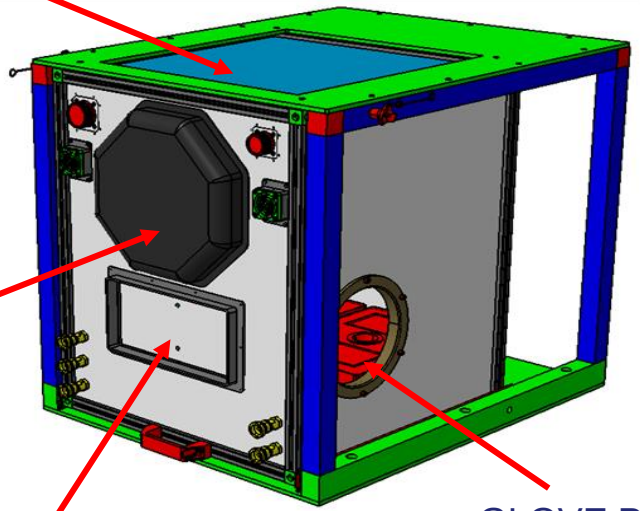
GCM – GROWTH CHAMBER MODULE

TOP WINDOW

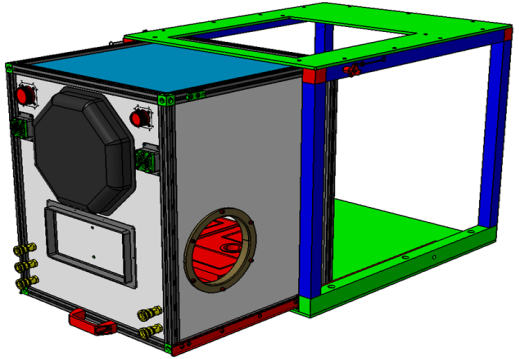
FRONT OBSERVATION WINDOW



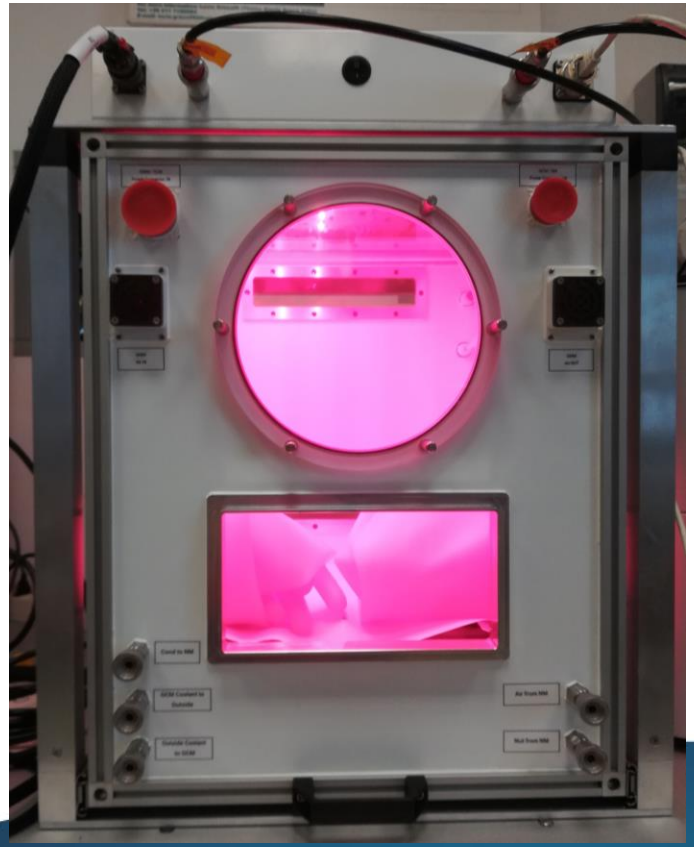
GLOVE PORT

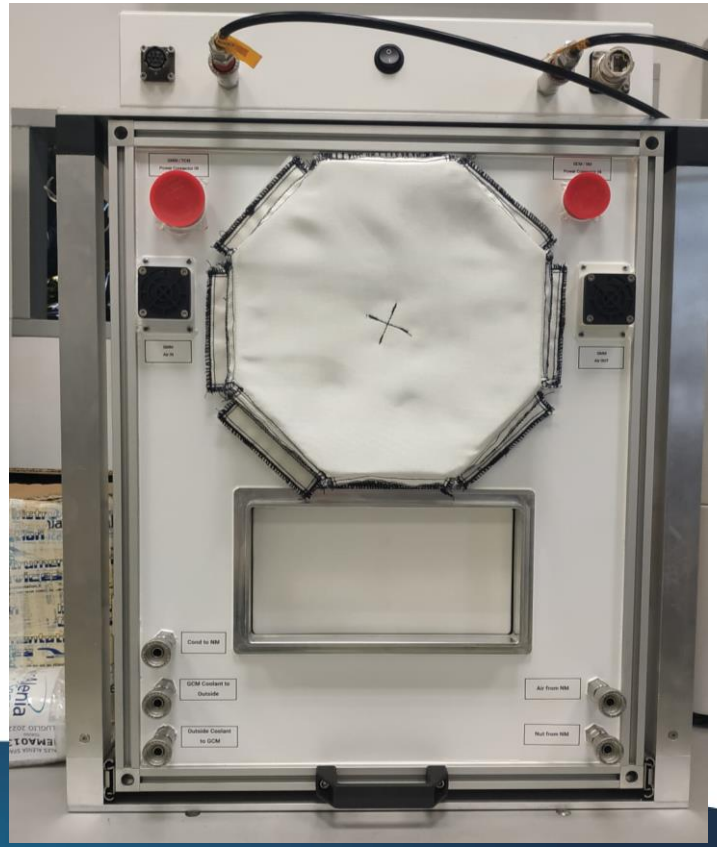
PASS BOX

GCM CAN BE EXTRATED FOR CREW OPERATIONS



GCM – GROWTH CHAMBER MODULE





GCM 2D CAD VIEWS: PRIMARY STRUCTURE

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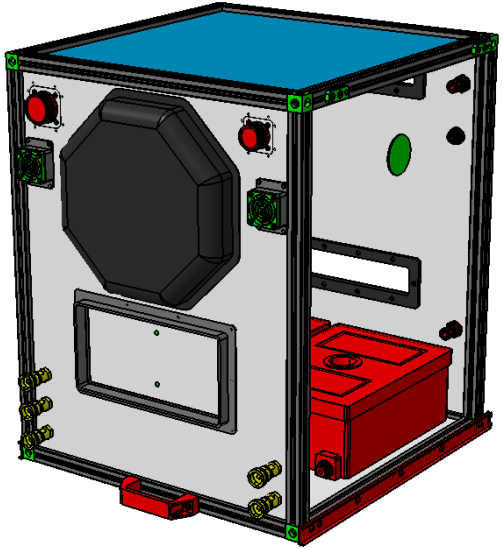
esa
European Space Agency

A



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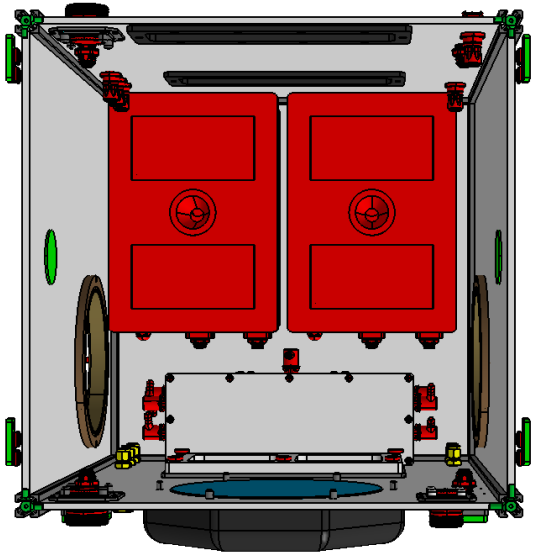

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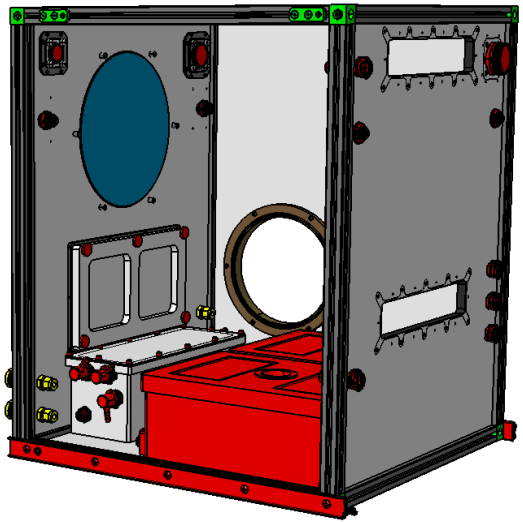
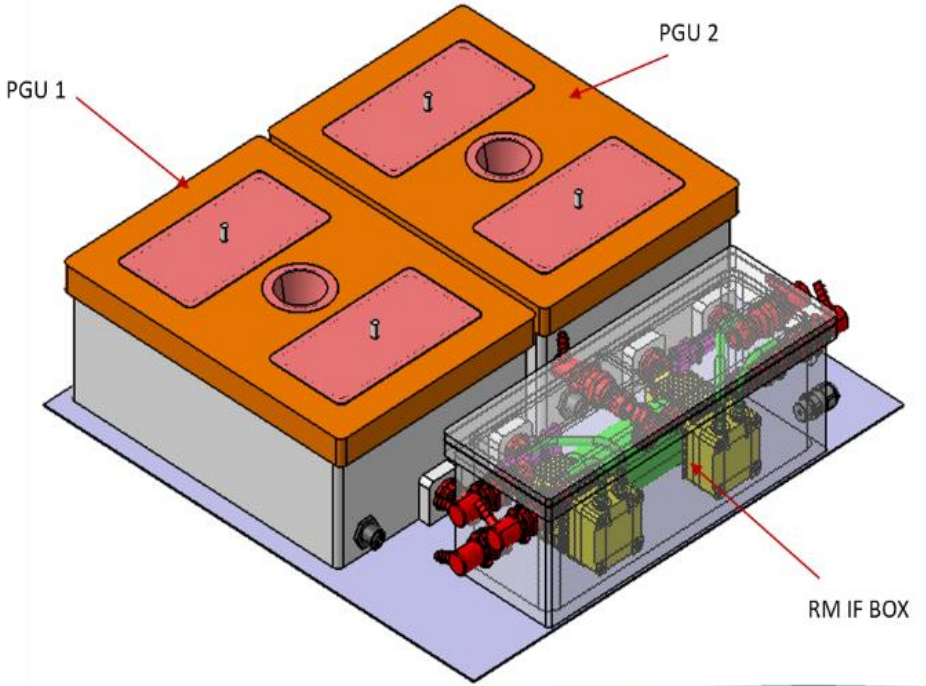


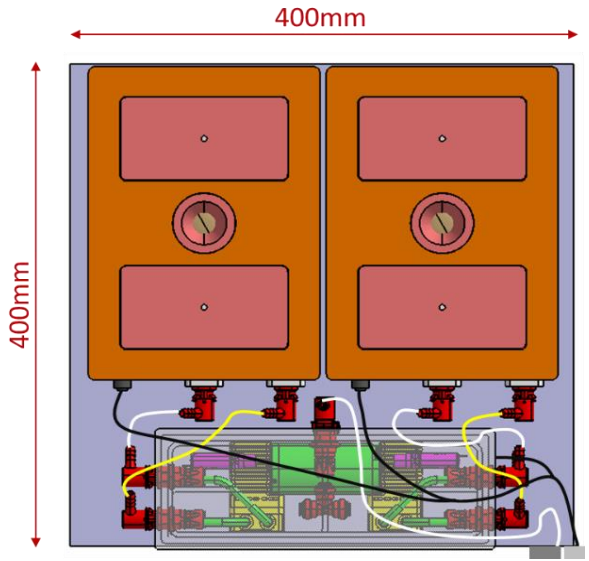
A) Front View detailing I/Fs located on front panel as well as inner PGUs.

B) TOP view detailing GCM PGUs and RM box configuration.

C) Right view detailing pass box lid position and I/Fs on rear side for TCM and GMM connection.

RM – ROOT MODULE

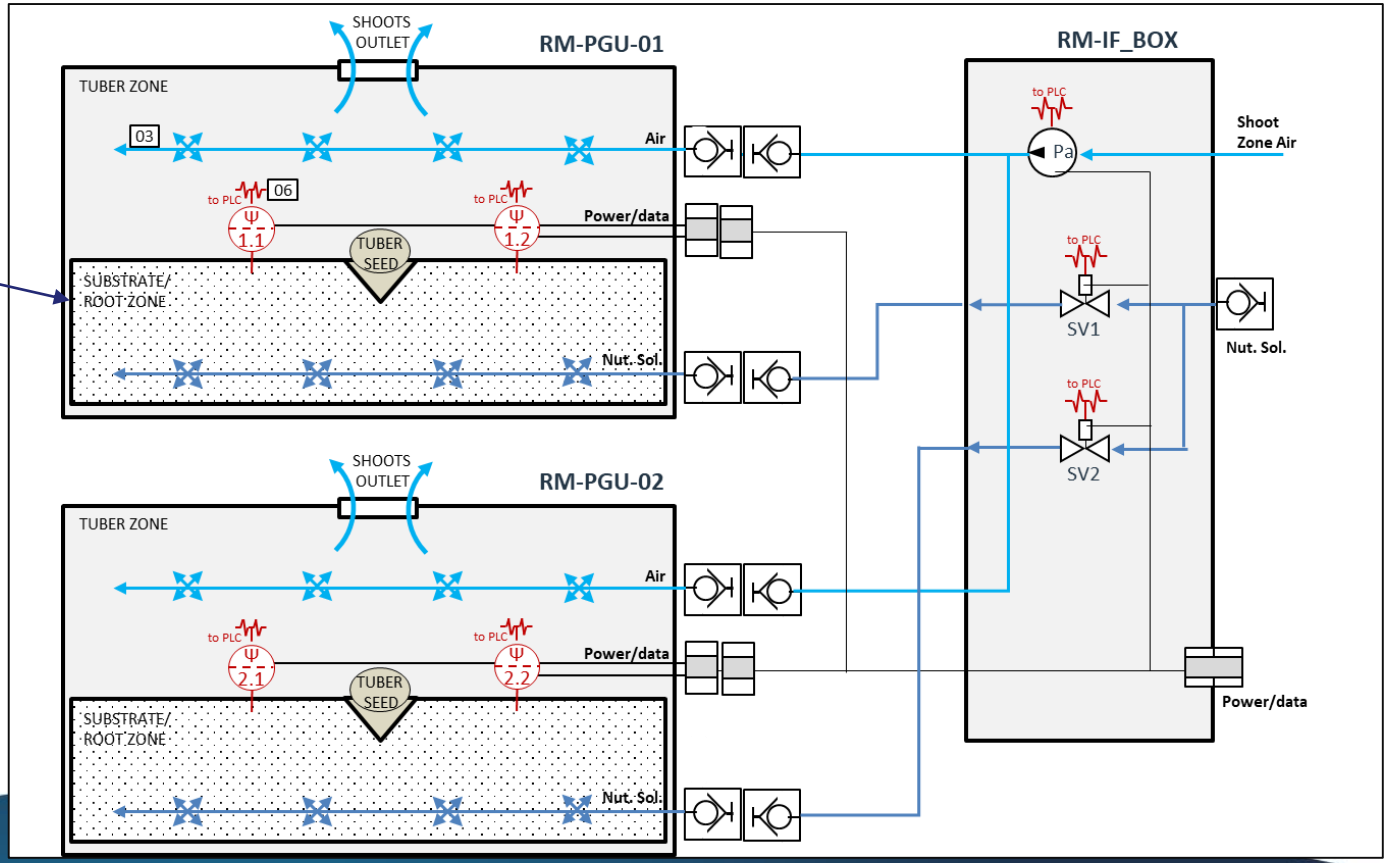




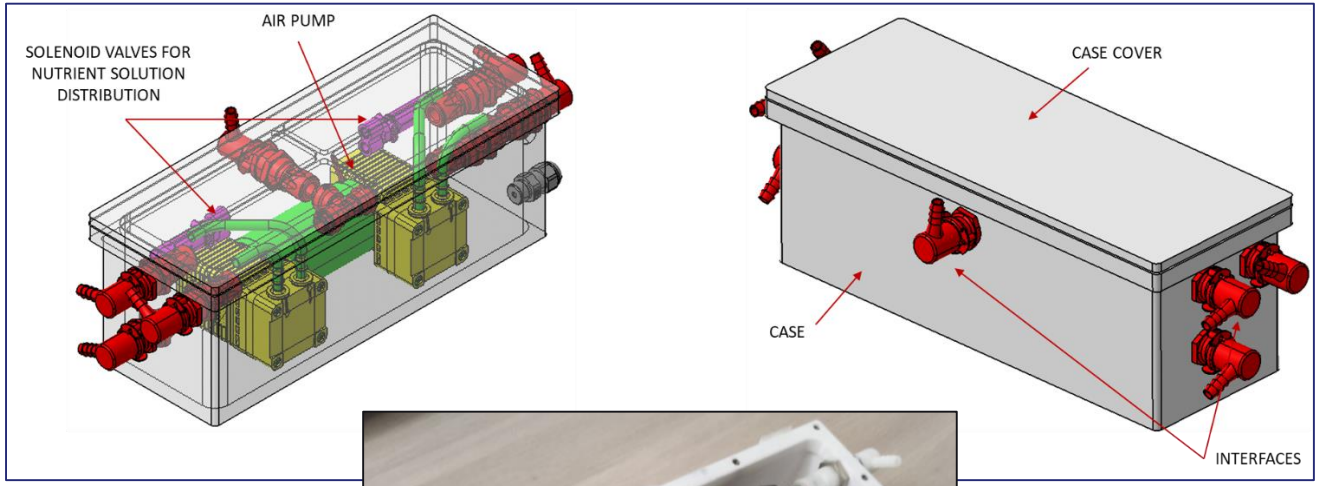
RM – ROOT MODULE

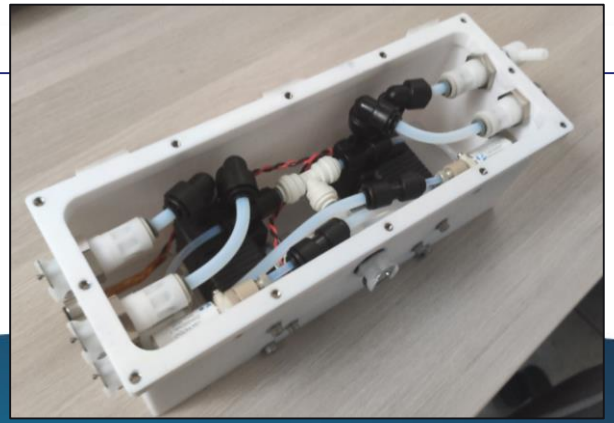
BASELINE
OPEN CELL PVA FOAM

OPTION
3D PRINTED ENGINEERED SUBSTRATE

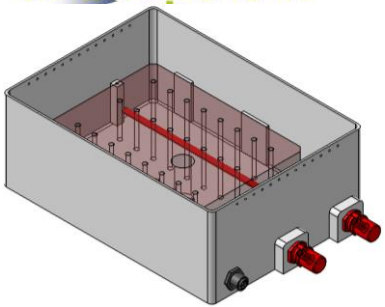


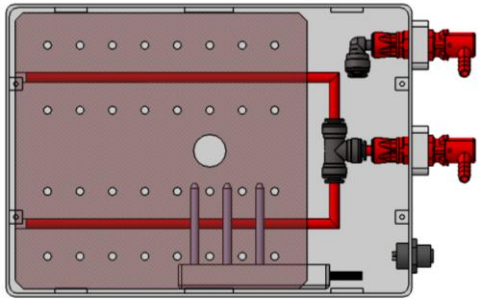
RM – ROOT MODULE

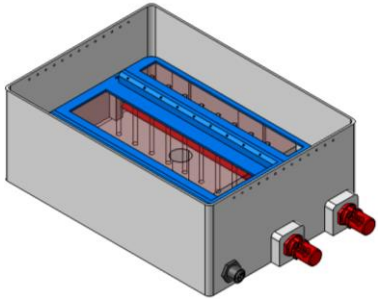


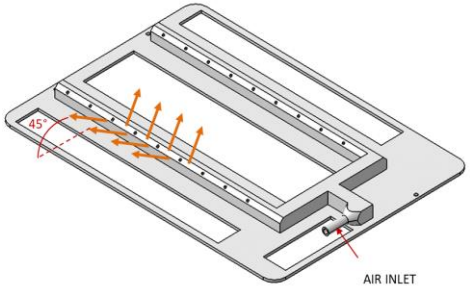


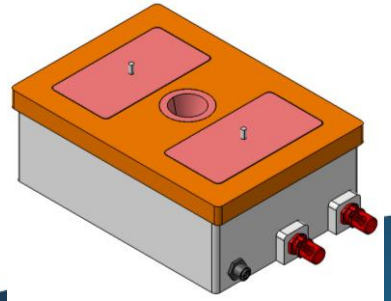
RM – ROOT MODULE

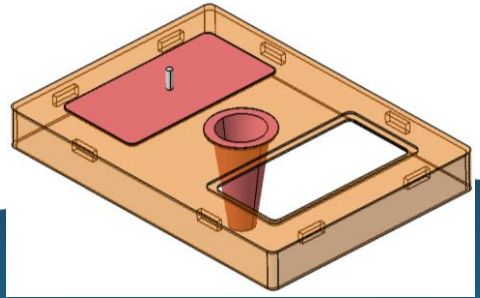


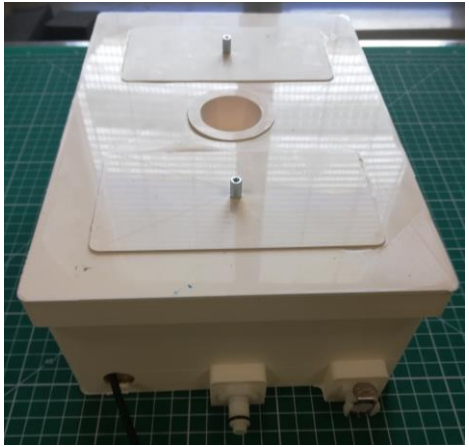












RM – ROOT MODULE

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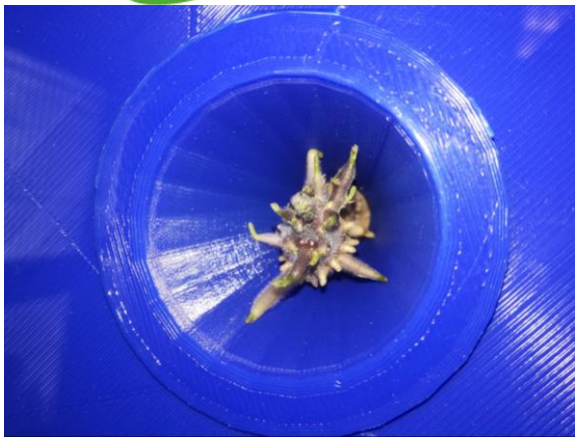
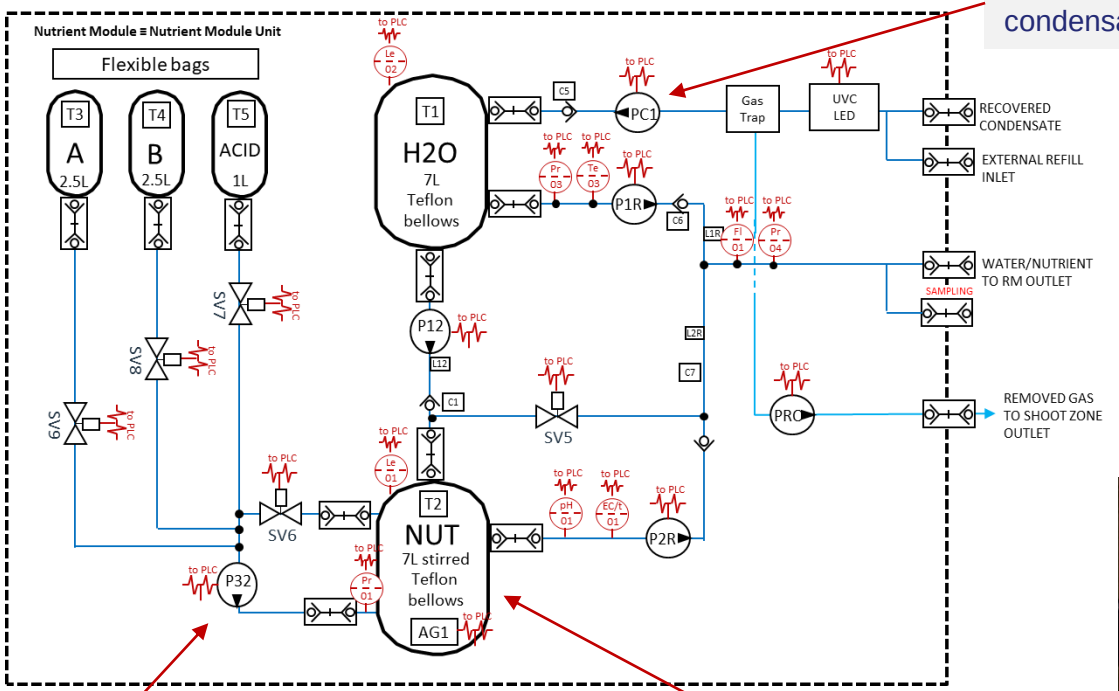
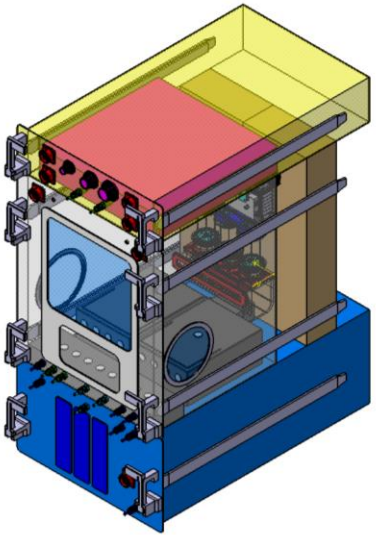





NM – NUTRIENT MODULE



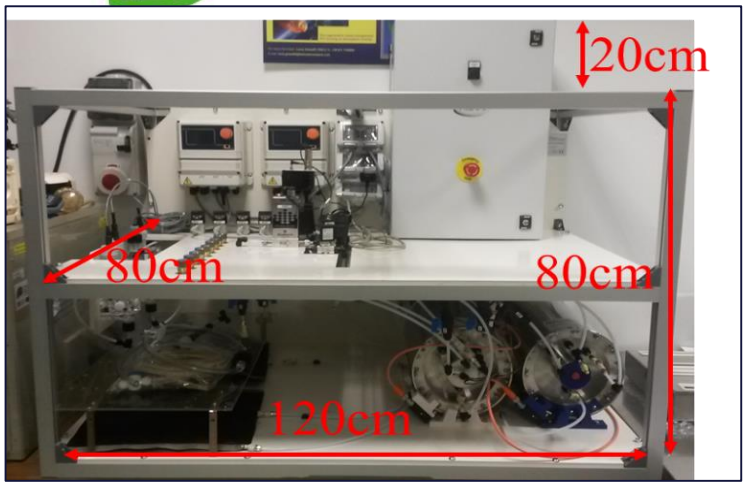
Recovered condensate line

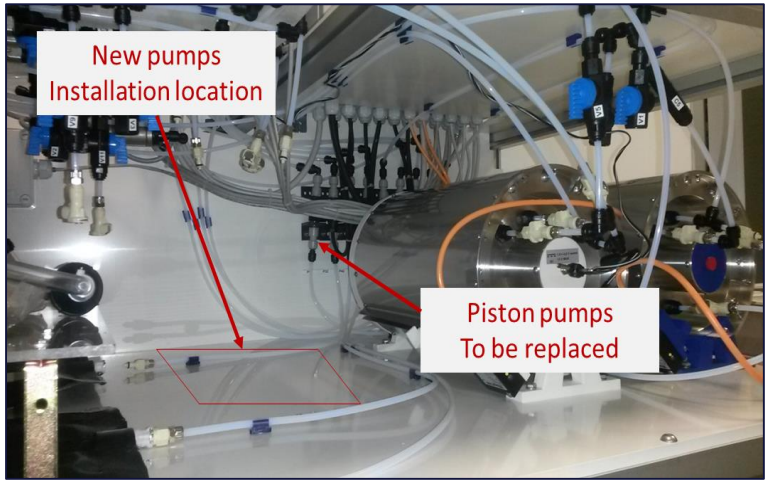


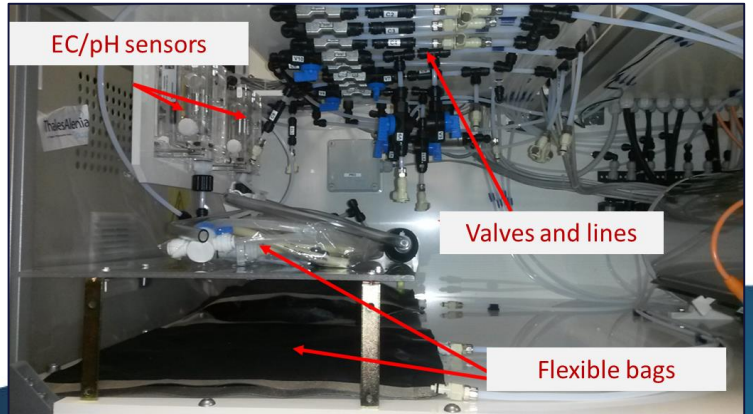
Precise pumping (0.1-3.0ml per injection)

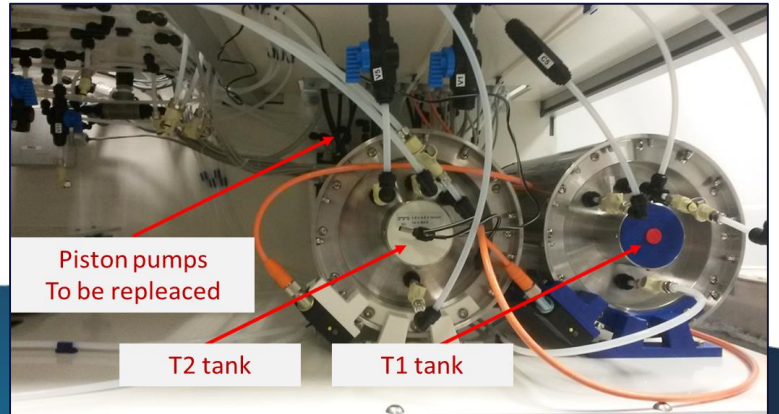
Stirred PTFE bellows reservoir

NM – NUTRIENT MODULE









LM – ILLUMINATION MODULE

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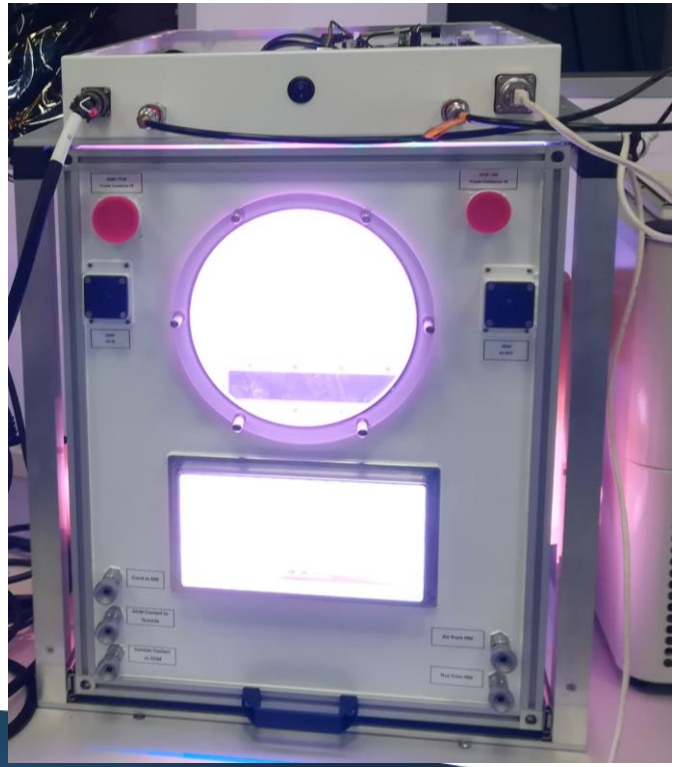
European Space Agency

LED	PPFD	PPFD
@max current	µmol/m2-s (at RM top)	µmol/m2-s (at 15cm from LED)
DEEP RED	350 ±5%	700 ±5%
FAR RED	10 ±10%	20 ±10%
BLUE	120 ±5%	240 ±5%
GREEN	90 ±5%	180 ±5%
TOTAL	1-570	2-1140

- Divided into 2 identical independent sectors
- Each Wavelength independently dimmable (currently in 10 levels)
- Programmable photoperiod

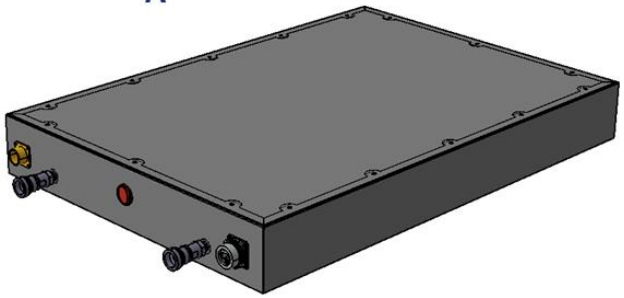


LM – ILLUMINATION MODULE

IN COOPERATION WITH

European Space Agency

A



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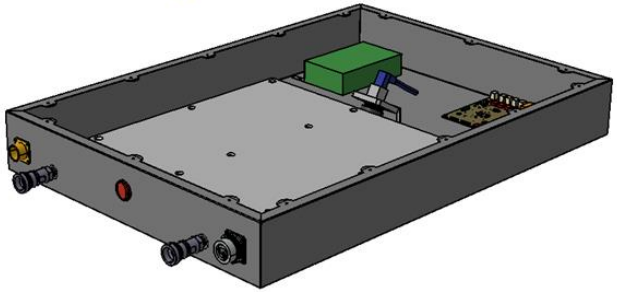
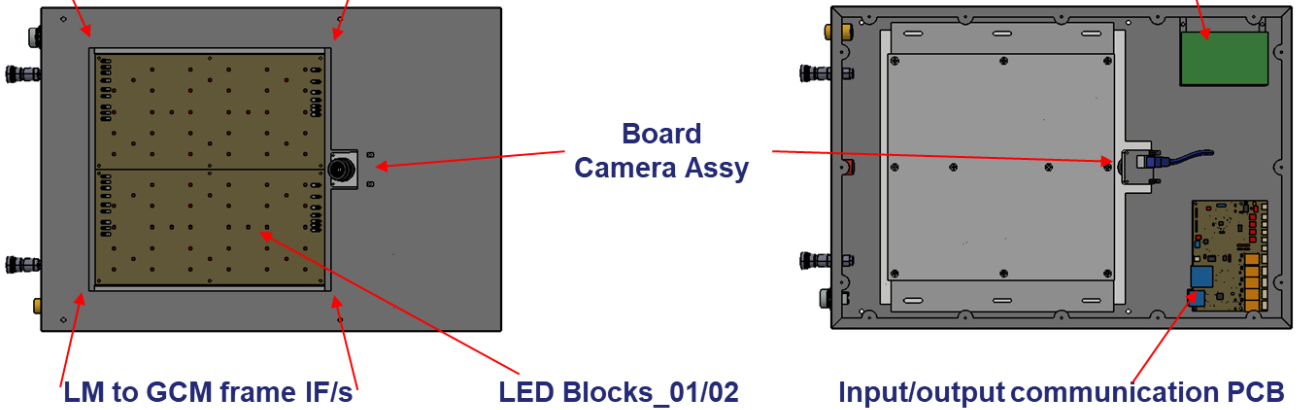
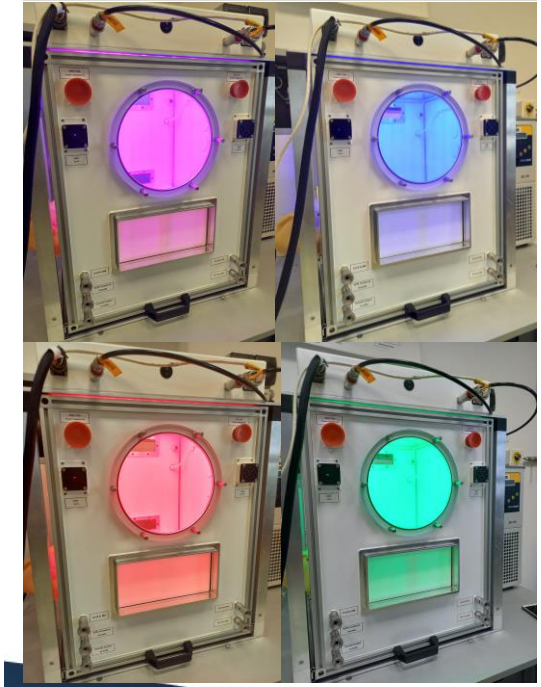


LM to GCM frame IF/s(01/02)

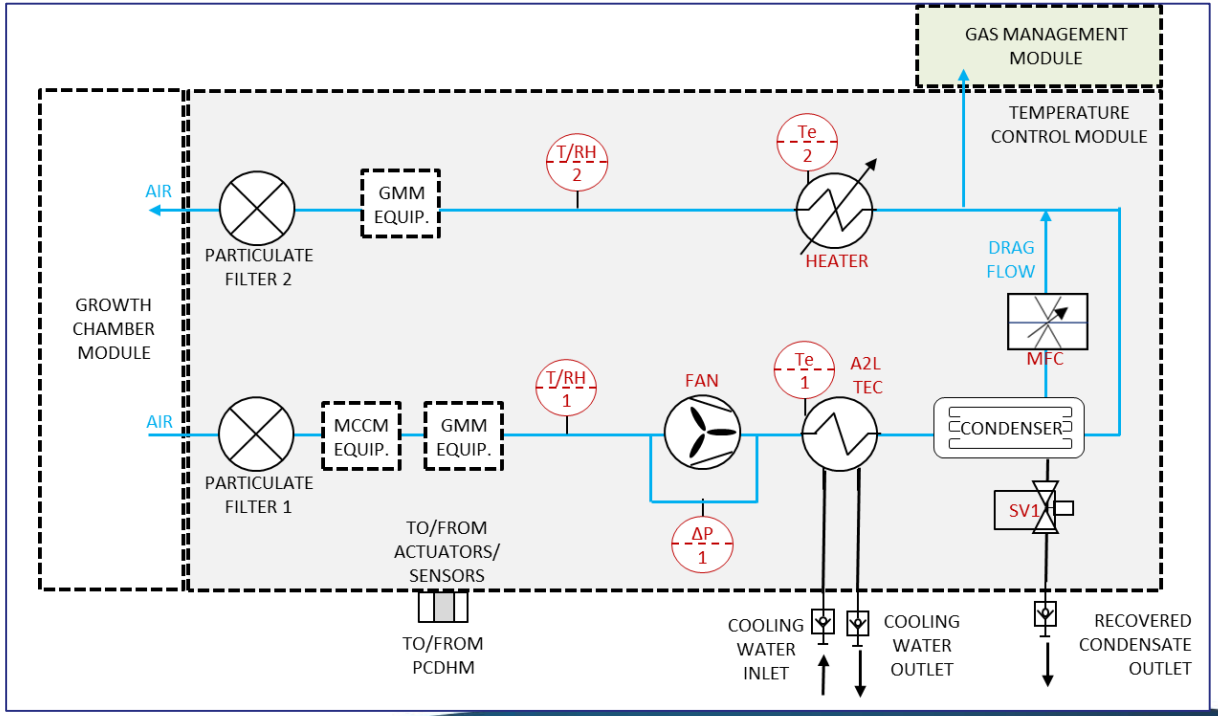
5-port Ethernet switch EDS-205A Series



JUST SOME SPACE ART

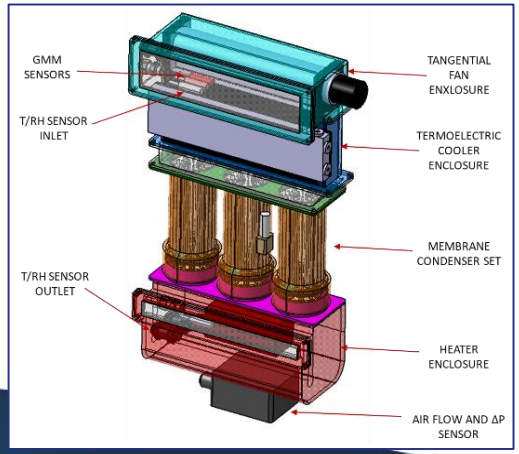


TCM – TEMPERATURE CONTROL MODULE

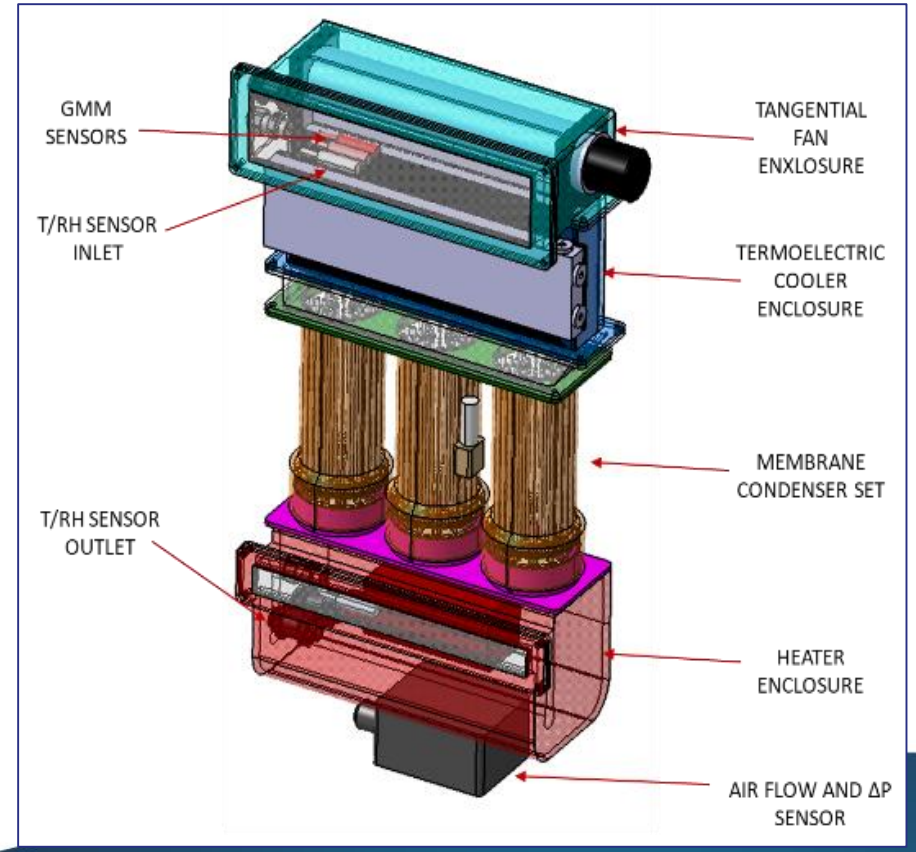


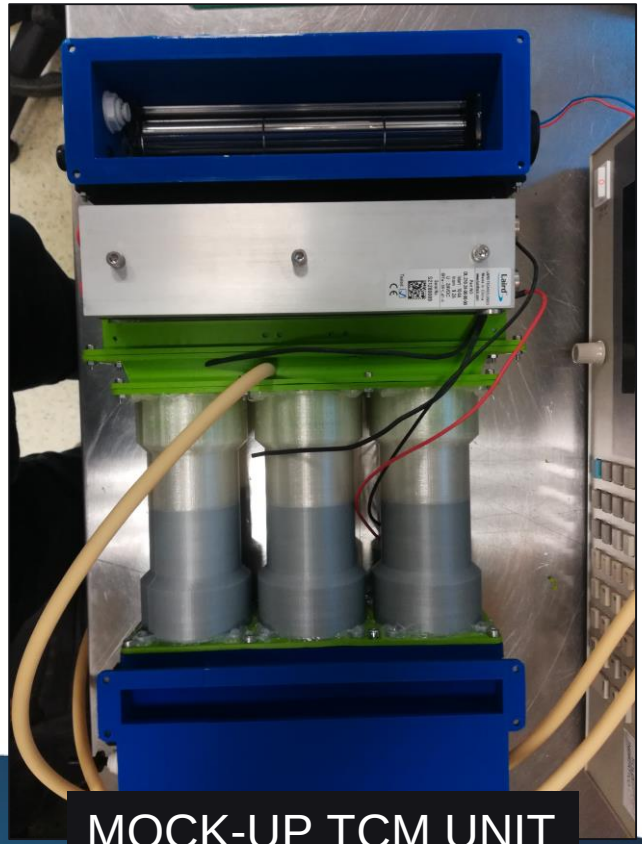
Temperature set-point
18-32°C ± 2°C
(LEDs power limited to 70%)

RH set-point
50-90% ± 5%
(only dehumidification)



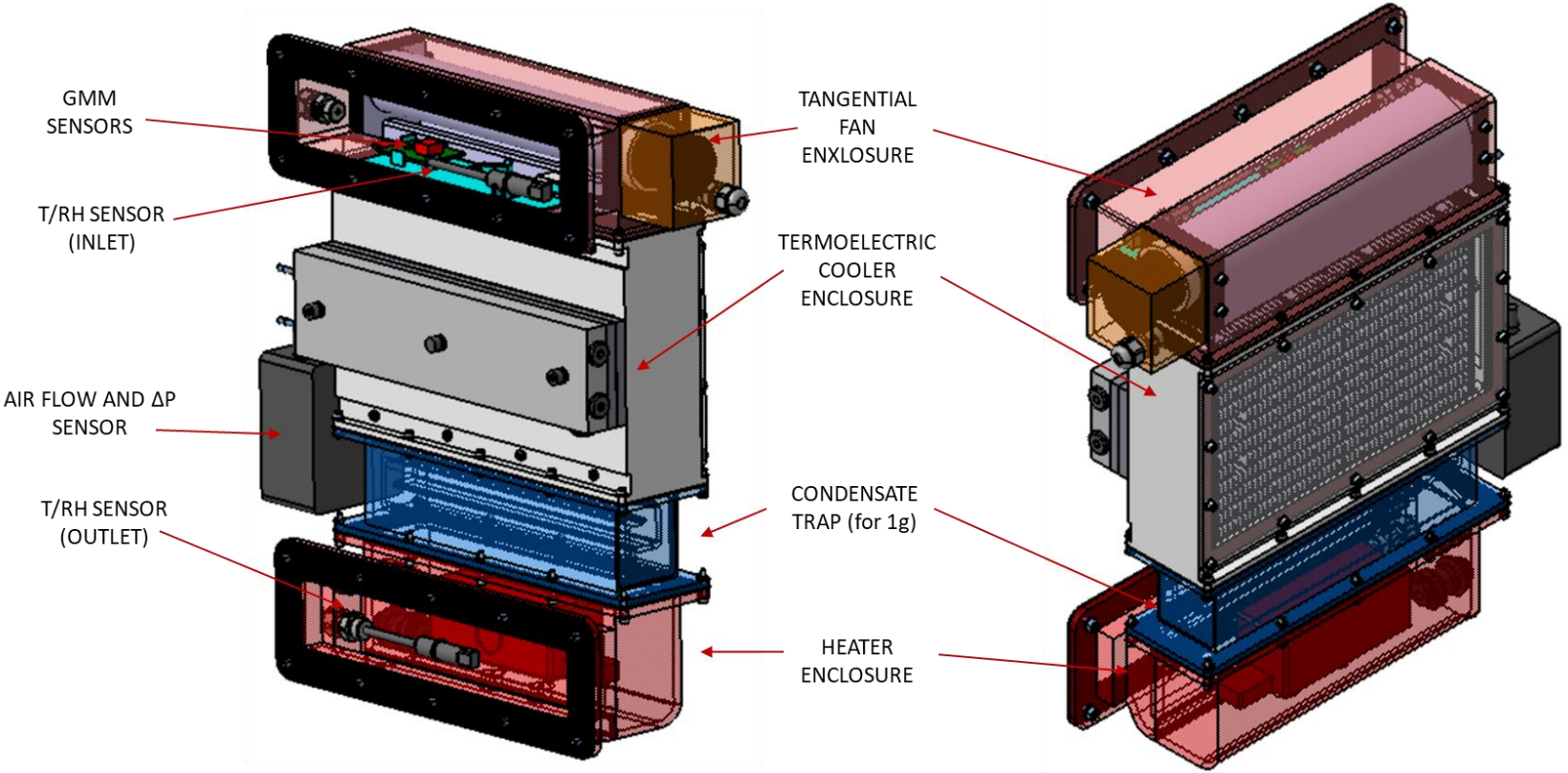
TCM – TEMPERATURE CONTROL MODULE



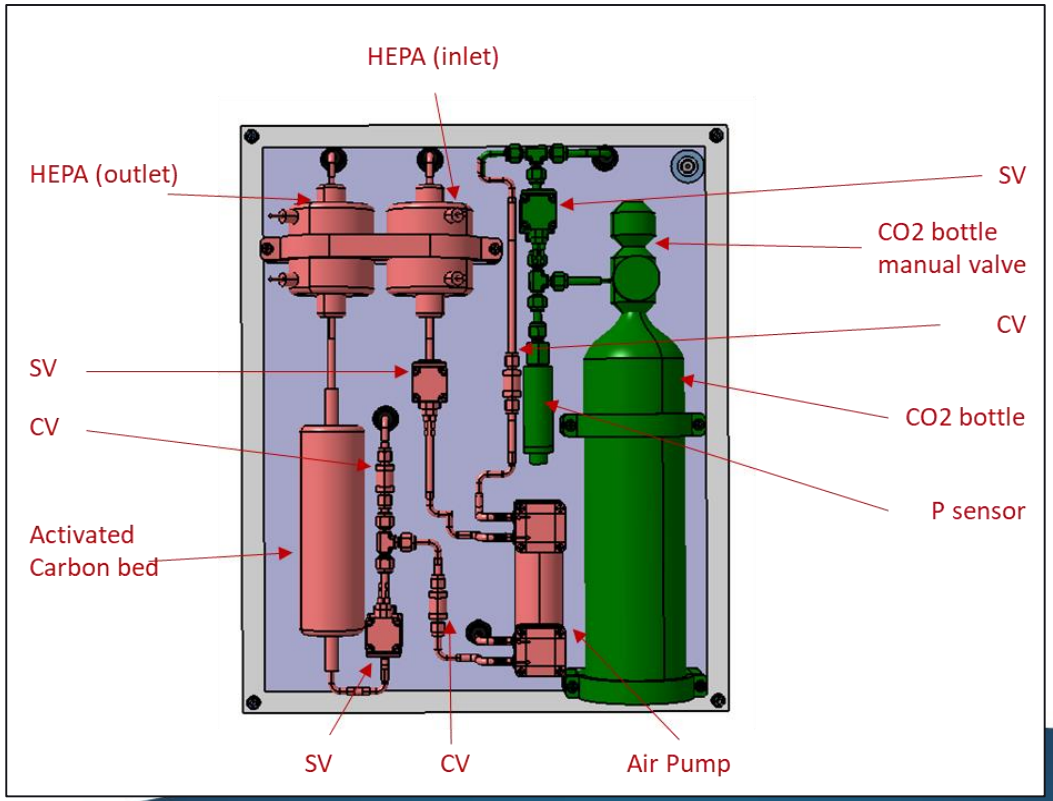


MOCK-UP TCM UNIT

TCM – TEMPERATURE CONTROL MODULE



GMM – GAS MANAGEMENT MODULE



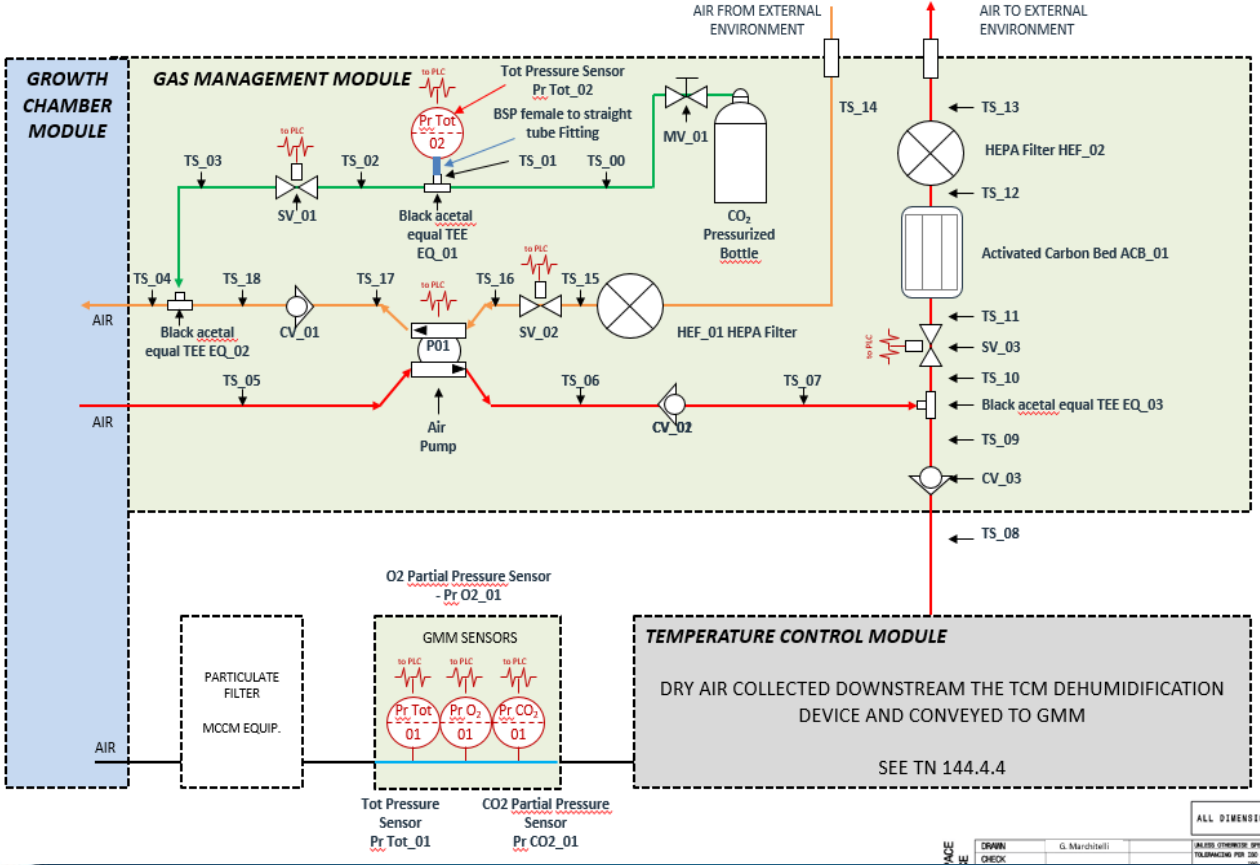
Highlights

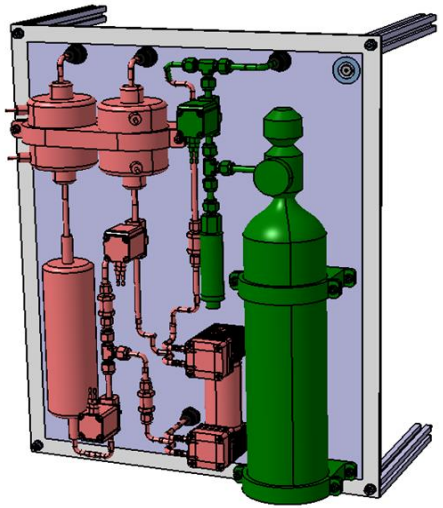
- [CO2] control: ambient to 4000ppm (precision is TBD, leak rate dependent)
- [O2] control: ambient to 23%
- Over-pressure control
- 0.2µm filter on laboratory inlet and outlet air
- Activated carbon filter on outlet air
- Trace gas filter in recirculation line
- 1 complete flushing of shoot zone atmosphere in 2h

Consumables

- 1 CO2 bottle used per growth cycle
- 2 HEPA filters per 3 growth cycles
- 1 AC filter per 3 growth cycles

GMM – GAS MANAGEMENT MODULE



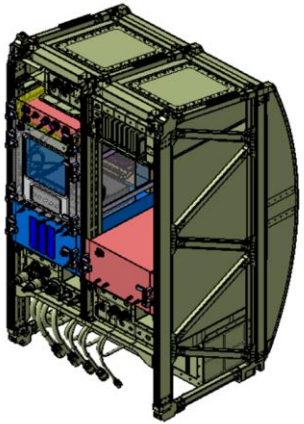


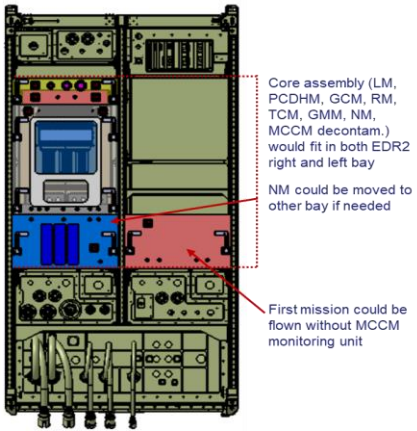
PFPU LONG TERM VIEW

IN COOPERATION WITH

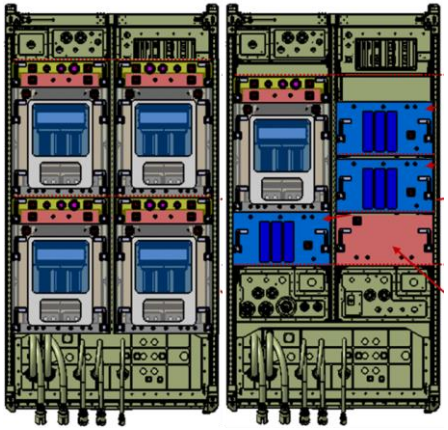
European Space Agency

PFPU
Technological Demonstrator for IOD on ISS (EDR2)





FPU
Food Production Unit for Mars Transit Habitat



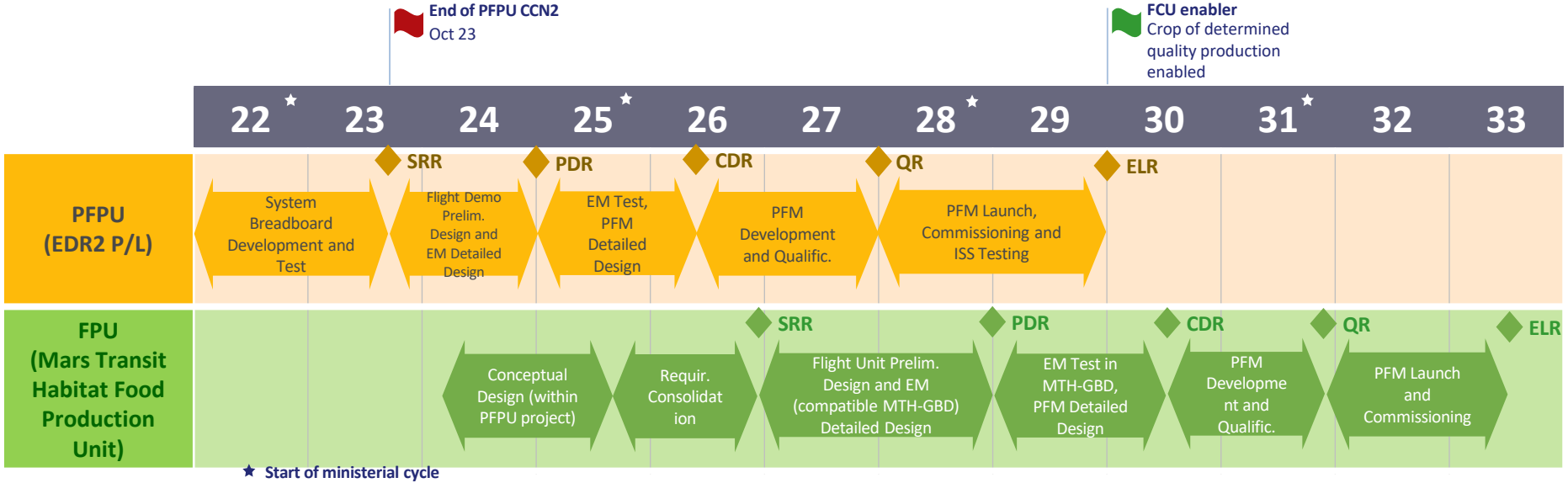
Need for ISS demonstration
Validate µg sensitive technologies
Validate crew operations in µg
Validate remote support strartegy
Evaluate interactions with crewed environment

Likelihood to be included in MTH
ESA declared ECLSS as flagship contribute to MTH
MELiSSA CIVb Compartment is currently included in the ECLSS preliminary design (see ESA MARGARITA CDF study)
It targets provision of a food complement (e.g. micronutrients)

PFPU LONG TERM VIEW

IN COOPERATION WITH

European Space Agency



MELiSSA

MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

This project has been funded by the European Space Agency in the framework of the ESA Contract No. 4000114057/14/NL/AT, concerning the PFPU (Precursor Food Production Unit) project.

The project is carried on in the MELiSSA (Micro-Ecological Life Support System Alternative) project framework in collaborations with The University of Naples Federico II Agronomy Department, the Institute of Membrane Technology of the Italian National Research Council (CNR-ITM) and the Norwegian Centre for Interdisciplinary Research in Space (CIRiS).

THANK YOU.

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